University of Maryland, Baltimore
New Administration Building

Baltimore, MD

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Executive Summary

The University of Maryland, Baltimore (UMB) is located in downtown Baltimore. They have recently finished construction on a New Administration Building. This building is the subject of the following thesis report. This 6 story, 107,000 SF Administration Building contains the University's executive offices and conference rooms. Construction started in March of 2007 and was completed by October of 2008. The total project cost is $27,500,000. Barton Malow Company (referred to as BMC) was awarded the Design/Build contract with a Guaranteed Maximum Price.

The following thesis will provide background information on the University of Maryland, Baltimore as well as the constructed New Administration Building. Also included are three analyses that have been completed over the last semester. The theme found throughout is implementation of energy conservation in buildings.

The first analysis topic deals with the rise in energy cost and the counter actions that colleges and universities are taking. College campuses are in a unique situation since conservation efforts must consider the entire campus instead of a single building. Three colleges were selected for study including, The University of Maryland, Baltimore, Pennsylvania State University and the Los Angeles Community College District. Although each school has its own strategic plan to conserve energy campus wide, many of the initial steps and strategies are similar. The conclusion will discuss which techniques are vital to universities looking to develop their own energy conservation plan.

The next analysis investigates the efficiency of the current building envelope and possible improvements that could result in energy savings. Preventing the inside, conditioned air from escaping through the envelope of the building can save significant costs on one's energy bill. This analysis will also look into the possibility of removing the finned tube heating units, found within the perimeter spaces, and effects this will have on the energy consumption of the building. Extensive thermal calculations have been performed to help compare the effects the proposed alternatives will have on the energy consumption of the Administration Building. Ultimately energy performance, in depth cost analyses and owner preference will if these alternatives will be implemented.

The last analysis examines the possible implementation of photovoltaic panels (PV) on the site of the UMB New Administration building. PV panels are a great way to harness the sun and convert its energy into electricity. Being located in the city poses unique challenges compared to surrounding areas. Careful planning and research has been done to determine products that work best for this location and calculations determined the optimum size, configuration, angle, and orientation. Cost and schedule impacts are analyzed to determine if photovoltaic panels are a practical application for this situation.

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1.0 Project Overview

1.1 Client Information

Founded in 1807, the University of Maryland at Baltimore (The University) is the oldest of the eleven (11) collegiate institutions, which, along with two (2) research institutes, comprise the statewide *University* System of Maryland (UMS).

The campus is comprised of the seven (7) University of Maryland Schools, which include Dentistry, Medicine, Pharmacy, Law, Social Work, Nursing, and the Baltimore Graduate School; the Thurgood Marshall Law Library; and the Health Sciences Library. The University of Maryland, Baltimore strives for excellence in all these fields and one way they achieve this is by providing world class facilities.

The New Administration Building promotes growth of the University. A new and better accommodating building advances organization, technology, and the ability to recruit the best faculty and students. Providing up-to-date facilities shows people the commitment of the UMB to stay at the top. Another example of this commitment is the beautiful and cutting edge Dental School that was finished just prior to the construction of the Administration Building.

With those considerations in mind the expectations for cost and quality are very high. This can be seen with the Design/Build approach, because it allows the Owner to be an important influence on what goes into the building. Having a guaranteed maximum price also shows that the Owner has a budget developed and will make sure that the project stays within this budget. This high level of involvement from the Owner is just another example of their commitment to excellence.

1.2 Project Delivery System

Design/Build was chosen for this project because the owner wanted it fast tracked. Not all the designs were complete but there was enough work to be done while designs and considerations were made. Barton Malow was awarded the Construction Management position with a Guaranteed Maximum Price Contract. They have worked with UMB in the past. In fact BMC was finishing the UMB Dental School, less than a block away from the site, just before construction. Also, Barton Malow has done Design/Build work which made them a suitable candidate. Below is the job organizational chart.

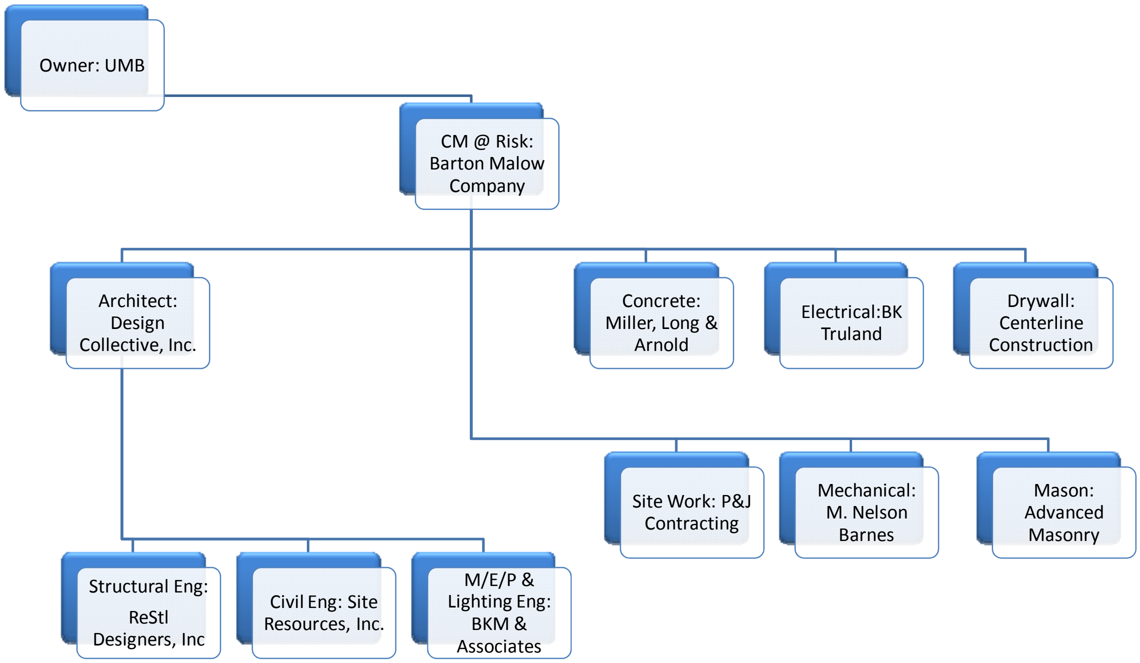


Figure 1.1 Project Organizational Chart

Barton Malow held all contracts with subcontractors and the architect. This made BMC @ Risk because they would be held liable for work that was not completed. All contracts were GMP. This offers some maneuverability, because if the design is a work in progress (Design/Build) then changes can be made to keep the cost under the budget with less of an overall impact.

Like most jobs, bids were accepted up until a due date and time. After that, no more bids were accepted for a specific bid package. The contractor who won the award was the one who met all the requirements and whose estimate was comparable to BMC's. This is public work and many times the lowest bidder is taken, but that is within reason. Extremely low or high bids can be thrown out. One requirement that Barton Malow had to meet is 25% MBE/WBE (Minority Business Enterprise/Women Business Enterprise) participation of total construction. This means subcontractors must either be or employ MBE/WBE businesses. For instance if the mechanical contractor is not minority or woman owned but their sheet metal supplier is, then that counts towards to project. Another requirement is that any contractor with over $100,000 in their budget had to furnish a bid bond, issued by a surety company licensed to issue bonds in the State of Maryland.

1.3 Project Team

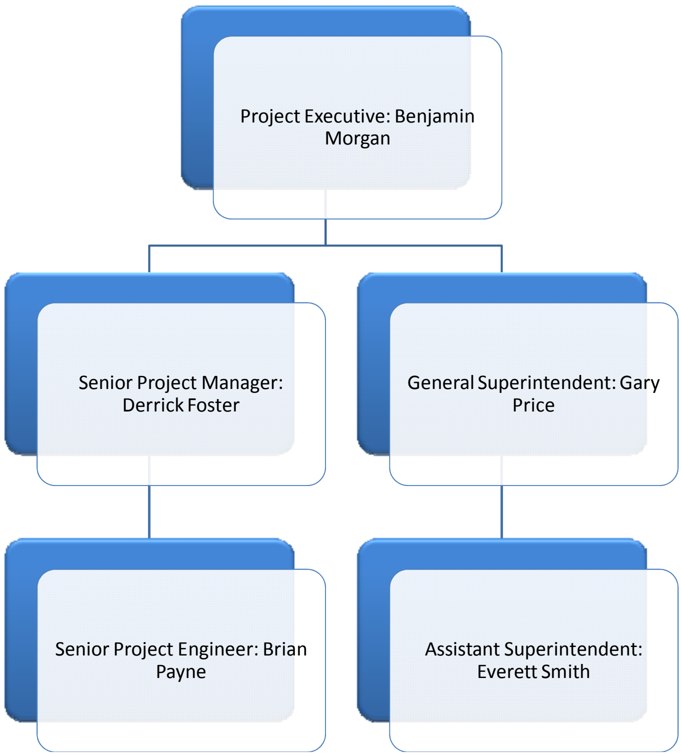


Figure 1.2 Project Staffing

The Project Manager is involved on a continual basis from commencement of the design until construction completion. This person will be responsible for the overall management of the design/build team and the completion of the project. The Project Engineer is delegated work by the PM. Much of the work entails retrieving submittals, request for information (RFI), keeping drawings up-to-date, etc.

The Superintendent is on site 100% once construction commences and will be responsible for the direct supervision of the trade contractors, daily coordination of the work on-site to maintain the schedule, on-site management such as material deliveries, outages, etc. The Assistant Superintendent is delegated work by the General Superintendent.

1.4 Existing Conditions

The UMB New Administration building is set in the city of Baltimore. This obviously leads to site logistic problems. Aside from the site itself Barton Malow was given half of Pearl Street (East) and the other half was to stay open for public use (both directions). They were also given the sidewalk of Lexington Street

(South). Arch Street (West) is one way flowing south and had to stay open because it leads to the UMB Administration current parking lot. The sidewalk adjacent to the site also could not be obstructed.

A small one story brick building had to be leveled to make room for trailers opposite the site. To the West of the site is a recovery center for cancer patients and to the North of the site is a day care center. These have inherent risks that need to be addressed (noise, sediment control, etc.).

Most utility plans, they are old and hard to read. This site has even more difficulty because the previous building had been vacant for some time, so points of connection are very vague. There are two proposed electrical entries into the building.

1.5 Building Systems Summary

1.5.1 Demolition

The UMB Administration site was occupied by a three story (with a basement), red brick building (with a basement). Aside from the building there was also an eight foot high brick wall surrounding the site. Demolition of this uninhabited shell started in November of 2007 and went until February of 2008.Being on the corner of a city block there were many risks that had to be addressed during demolition. On the South, East, and West sides of the site there are three streets with moderate vehicular traffic. Possibly the biggest concern of demolition and all throughout construction is the day care neighboring the site directly to the North. The property line was right against this day care and because the site was already tight, all available space had to be utilized. Extreme care needed to be used by the operator to ensure all debris stayed within the site. Luckily no hazardous materials were found during demolition.

1.5.2 Structural

The entire building was constructed of cast in place concrete using a combination of crane and bucket and pump truck. Utilizing post tensioning, a slab thickness of 9 inches was achieved. The tendons, in the North/South direction follow the column lines. The East/West direction is more difficult to see a pattern.

For the super-structure the floors were split in half and constructed in a staggering fashion to allow contractors to work continuously. It meant work did not have to stop while pours were conducted.

The slabs were formed using multi-use plywood and scaffolding the entire floor area. Forming, laying tendons and rebar, and setting pipe penetration inserts took about 4 days and pouring would begin on the 5th. Slabs were poured using a pump truck and could be done and one day. The concrete was given 3 days to cure and then the tendons would be stressed. 5 days after the pour, the forms were stripped and reshores were placed underneath, until the concrete reached full strength.

The layout of the columns is pretty uniform throughout the building. Typical bays are 30’x30’. Columns followed the same pattern as the slabs. Columns were erected the day after the slab was poured. The column cages that were fabricated on the ground were tied in to bent bars coming up from the slab.

Unlimited-use, "Doka", forms were used for the columns. Crane and bucket was used to pour the columns and a half of the building worth of columns could be done in three days.

1.5.3 Mechanical System

The Mechanical rooms are located on the first floor in the Northeast corner of the building. There is an attached room dedicated to the hot water system. On the roof there is a custom made 90,000 CFM Air Handling Unit that services all 6 floors of the building.

The UMB New Administration Building utilizes Forced-Circulation Air-Cooling and Air Heating-Coils. There are 8 glycol air conditioning units throughout the building. There are various heating and cooling terminal units including, finned tube radiation, convectors, electric unit heaters, cabinet heaters, and coils. To control air volume in different zones, this system uses Single Duct Variable Air Volume. The entire system is automated with sensors to monitor and control the environment within a space.

The entire building is equipped with a wet sprinkler system that has broken up each floor into zones and ensures that 100psi is available at the most remote fire hose connection in the system.

1.5.4 Electrical System

The electrical system is fed by a 200KW generator set rated 208/120V, 3 phase, 4 wire. This generator feeds dual 15kV switches and steps down to a 750kVA transformer. Areas are lit by various sized fluorescent lights.

1.5.5 Building Envelope

Brick veneer is used to encase the building everywhere except for where curtain wall is present. The facade is accented with soldiers and header courses around the roof, second and fifth floors. Tiebacks connect the brick to the metal wall framing.

Mast climbing scaffolds were set up on the North, East, and West sides of the building for the exterior closure/masons and moved up the exterior walls as the courses were laid. Every floor the scaffold was tied into the building structure much like a hoist. Due to the length of the building sides, 4 masts were necessary for support.

Wrapping around the Southwest corner is an 878 SF curtain wall. This is the main architectural feature and also the main entrance to the building. It starts just after the first floor and extends 27.5 feet high. The main panes are 8 feet 7inces tall and 6 feet wide.

The curtain wall is comprised of glazed aluminum. Accenting the main entrance curtain wall are metal wall panels and more glazed aluminum instead of the brick veneer which is found on all other sides. Telescoping lifts were used to set the curtain wall after it was framed in during enclosure. Being on the corner with the highest volume of vehicular traffic, there was not much room to maneuver. This emphasizes the need for detailed scheduling.

1.6 Site Layout Planning

Site plans can be found in Appendix A.

1.6.1 Excavation

Excavation of the site was done with a large excavator, 2 loaders, and trucks coming by to remove spoils. There are 2 piles of spoils located near the 2 entrances to the site. This utilizes the entire site as well as minimizes the congestion on the roads. At this point there was only a Barton Malow trailer on site with no utilities.

1.6.2 Superstructure

When substructure and superstructure began, Barton Malow's management team was present on a daily basis. The concrete contractor had a trailer onsite as well but not in the small trailer lot across from the site. As soon as foundations for the elevator core were complete a tower crane was erected. It was used for transporting materials as well as pouring the columns via crane and bucket. To pour the elevated slabs a pump truck was used. When the South end of the building had to be poured the crane would reach spots that the pump truck could not. The pump truck could only park where it is located on the plan (Northeast corner), otherwise it would block traffic and in the contract that was not allowed. In the Northwest corner is where rodmen fabricated the column cages. There was no on-site parking for workers but cars were tolerated until more trailers moved into the lot with Barton Malow.

1.6.3 Façade

Construction of the façade was done by scaffolding the entire length of 3 sides and having the masons complete that entire side. Once done they would move on and then the rest of the finishers would get to work. Lifts were utilized for the curtain wall and storefronts. Yet another potential coordination challenge due to the compactness of the site.

1.7 Detailed Project Schedule

Construction for the UMB Administration Building began March 29th, 2007 and its scheduled completion was September 29th, 2008, with the owner being completely moved in by October 21st.

The building was broken up into two halves during foundation and superstructure construction, North and South. The North foundation began slightly before the South so that the North's superstructure would begin before the South's. Having the concrete erection split into North and South allowed the structure to rise vertically without being completely finished underneath. For example, level 2 North and South would be at different stages in forming/reinforcing. Level 2 North would pour before level 2 South and the next day forming could begin on level 3 North. While level 3 North was forming, level 2 South would be poured and the next day formwork for level 3 South would begin. This staggered construction continued all the way up the building and allowed trades to work continuously.

Building enclosure began on level 1 while erection of the fourth and floors above was still underway. A month after enclosure began rough-in and finishes of level 2 started and would continue up following enclosure. Staggering is also seen with rough-in and finishes, although not broken into North and South.

Owner move-in follows the balancing and inspection of the buildings systems which commenced when the majority of the finishes were completed, September 30th 2008. To see complete project schedule see Appendix B.

1.8 Project Estimate Summary

The project estimate provided by Barton Malow came in at $27.5 million.

Item	Division	Cost/SF	Cost
Foundations	01	$5.47	$589,208.00
Substructure	02	$2.92	$314,973.00
Superstructure	03	$21.05	$2,799,313.00
Exterior Closure	04	$29.62	$3,228,629.00
Roofing	05	$2.86	$327,702.00
Interior Construction	06	$32.12	$4,145,001.00
Conveying Systems	07	$3.95	$451,500.00
Mechanical	08	$46.40	$5,258,137.00
Electrical	09	$19.15	$2,191,941.00
Trade General Conditions	10	$4.96	$534,325.00
Site Work	12	$11.64	$1,293,730.00
Total Project (including Fee)		$256.85	$27,500,000.00

Figure 1.3

2.0 Collegiate Reaction to Escalating Energy Costs – Critical Industry

2.1 Problem

"The United States consumes 25% of the world's energy, while making up only 5% of the populations," a direct quote from Penn State's OPP website. This energy is getting more expensive everyday and it does not appear to stop any time soon. Since these increases cannot be instantly brought to a halt, communities and owners must take a proactive role to combat the current situation. It is one thing for a building owner to make strides towards energy conservation in a single but it is a very different thing for a university to do the same. Universities have to consider initial cost and payback periods on a much larger scale. For their approach to have any significant effect on the annual energy bill, solutions must incorporate large portions of the campus instead of a single building, which can limit the types of strategies that can be implemented. Universities also have to deal with the diverse building uses such as 24 hr labs or libraries, late classes, and other buildings that need electricity and conditioning at off hour times. This intertwining of buildings' systems in combination with the diverse building uses requires thorough and detailed planning.

2.2 Background

Three universities were chosen for research about what they are doing to reduce their energy usage. These universities include the University of Maryland, Baltimore, Pennsylvania State University, and the Los Angeles Community College District. Each is feeling the effects of the energy crisis and making major strides to "green" their campus.

2.3 Goal

The goal of this research is to learn strategies that can help college campuses be more energy efficient and can be implemented on other universities around the country. A recommendation of what vital, initial steps should be taken if another university would like to conserve energy and save money.

2.4 Methodology

1. Conduct interviews and research on the University of Maryland, Baltimore.

2. Conduct interviews and research on the Pennsylvania State University.

3. Conduct interviews and research on the Los Angeles Community College District.

4. Consolidate all the information and look for similarities and differences between the colleges.

5. Collect the strategies that can be implemented on campuses regardless of location.

6. Conclude and discuss the necessities involved in creating a conservation plan.

2.5 University of Maryland, Baltimore

As mentioned before UMB is located in downtown Baltimore, MD. This location, very congested and found between the PA, MD, and DC electricity grid, often is the first to see the rise in energy prices and in turn the benefits of conservation. The campus includes 62 buildings within 61 acres. Some of these buildings include medical and dental clinics, labs, libraries and administration offices.

Figure 2.1 UMB Buildings

UMB is committed to conserving energy. In 2006 they signed the American College and University Presidents Climate Committee, which required the University to draw up a Climate Neutrality Plan with concrete steps and achievements. They also are a part of PJM's Demand Response Program which pays the university for reducing its peak hour load demand and overall consumption. A senior facilities manager from UMB said, "UMB is in a unique position of leadership and influence to serve as a model promoter of progressive ideals in the areas of energy conservation, resource management, and green design." This commitment and model he speaks of is shown by the fact that in just 2 years the university has lowered its annual energy load by 20 million kWh. A significant feat for anyone, this accomplishment is amplified by the fact that at least 2/3 of the spaces need 100% Outside Air. This is due to the many labs and clinical spaces. The university is also contracted by the National Institute of Health to perform research with highly volatile materials, such as anthrax. Location also poses problems for the buildings because being near the inner harbor there is lots of humidity. Humidity can sometimes be worse than heat. Humid air must be cooled very low until the moisture is removed and then must be reheated to the set temperature level. Along with these obstacles, its city location can pose special problems.

With 62 existing buildings, a large emphasis is placed on retrofitting these buildings. Being a university older than 200 years there are old inefficient buildings contributing to high energy load. One of the obstacles of conservation is knowing where the biggest effort is needed. UMB teamed up with Comverge to develop a centralized automation system. Comverge's Real –Time Economic Load Response Program and Reliability Pricing Model monitors data at 66,000 points around the campus and provides vital information to better use energy. All this information is fed into a central command center that has the ability to control the building systems on every building on campus. Alfred Ruppersberger, Campus Operations and Energy manager, said, "Every morning, we review the forecasting email from Comverge. We then look at how we anticipate power demand throughout the day and adjust accordingly." Some of this information and actions are listed on the next page:

- Monitor real-time market pricing
- Develop load profiles
- Create customer baselines
- Energy audits to measure potential energy savings
- Periodic on-site assessments
- Metering and system integration
- Analyzing and graphing tools

Lighting can account for 10%-20% of a buildings energy bill so UMB has done much in this regard. They have installed occupancy sensors that are turned on during occupancy hours to allow lighting only when people are using the space. Some spaces are also fitted with sun sensors that control the lighting intensity based on the sun's presence at that time. To assist in reducing the energy wasted by lights that are left on and things of that nature, the university also uses "smart breakers". These breakers contain a network chip that can communicate with the central command center. From the command center UMB can open and close the breaker based on the time of day and use of the space. This prevents scenarios of people working late or housekeeping leaving the lights on. Workers can schedule times with the university when they need rooms lit during off hours and the command center will input the times to close and open the breaker automatically. The last lighting improvement is retrofitting old light fixtures with new, more efficient fixtures (T-8 to T-5). This can be done fast and has a very short payback period. The only drawback is that the light output is much greater in T-5's so the fixture layout may need reconfiguration.

As mentioned before the university is required to provide 100% OA in many of the buildings on campus. This major load results in multiple large chiller plants around campus. UMB has installed underground pipes to connect all these plants in a loop. The command center receives information about the load requirements at that time and responds accordingly. Much like the lighting system the air flow of the Air Handling Units is reduced during off hours. The temperature setting does not change but with no people occupying the spaces the heat load is reduced significantly and so less conditioned air needs to be delivered to the space. Because of the loop, 1 or 2 of the plants can serve the entire campus and if demand increases more can be turned on as needed. This allows the chiller to utilize close to their full capacity which makes them run at a much higher efficiency. These plants also make ice during off peak hours and store for cooling during peak hours. This is one of the ways the peak load is dropped and the benefits are seen from the PJM Demand Response program.

Since most of the conditioned air cannot be re-circulated, due to 100% OA requirements, many buildings utilize energy recovery systems. With these systems the pipes containing the conditioned air, which is being exhausted, are coiled and the fresh outside air passes over these coils. This brings the fresh air to a temperature closer to the design temperature and thus takes less energy to condition. For example, in the winter months air that has been heated and exhausted will heat incoming air before it even reaches the heat exchangers.

For new construction much of the same techniques that were explained above are also being implemented. One thing that UMB is emphasizing for new construction is task lighting. Task lighting is what it sounds, providing light specifically where it is needed instead of flooding an entire room. This is important with the labs and open office spaces. Significant light is needed for these activities but only at the lab bench or desk. Lights are provided under shelves with controls available to the person allowing them to create the optimum light level, while the ceiling lights remain off. Even during occupied mode the ceiling lights are less intense. While the ceiling lights are shut off during un-occupied mode, the task lighting is not controlled by the command center and can be turned on at anytime.

UMB is also working through LEED and USGBC to create energy models to accurately predict the consumption of the proposed building. From preconstruction to retro fitting predicting and responding energy consumption is the key to making and entire campus more efficient.

2.6 Pennsylvania State University

Penn State predicts that energy related commodities cost will double in the next five years due to the “current energy market volatility.” This will have a major impact on a university that uses 400 million kWh of electricity a year. The Pennsylvania State University has a variety of plans in place to combat this problem at all stages of a buildings life, new construction to retrofitting buildings and everything in between.

Each person on campus is responsible for about 20 kWh and 10 lbs of coal each day. As a large member of the State College Community, one of PSU’s biggest focuses is creating awareness among students, faculty, and staff. It takes a proactive, responsible part in making sure people realize their own impact on the conservation efforts of the university. Most energy consumption is the result of a decision made by people everyday. The OPP website has countless materials explaining the facts and giving helpful and easy tips for people to do their part. There are multiple pages just like the one on the next page that are specifically made for students, faculty, etc.

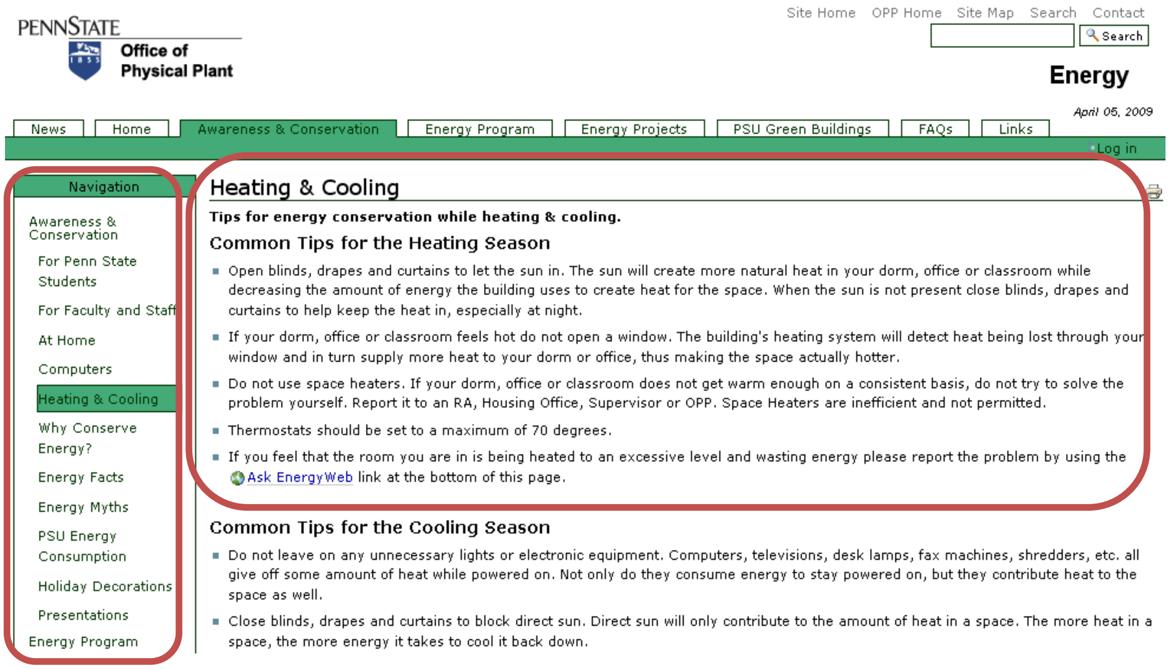


Figure 2.2 OPP energy website

A comprehensive presentation was also given in 2007 titled DIY (Did You Know) Energy Savings. Moreover, the awareness PSU is trying to get out there is stapled and thumb tacked all over campus. In every building there are signs about recycling and turning off lights when done.

Figure 2.3 Old Main winter of 1973

Penn State started its energy conserving in 1973 with the Winter Setback. The university began turning the buildings' temperatures down to 55°F during winter break and saves $100,000 to $200,000 annually.

It is believed to have saved the university upwards of $4,000,000. Since then there have been many other advances in cutting down on the college's energy consumption. The plans that will be discussed include:

- Guaranteed Energy Savings Program (GESP)
- Enterprise Utility Management Solutions (EUMS)
- Continuous Commissioning Program

It will be seen that much of what the University of Maryland, Baltimore is doing to conserve energy on their 62 building campus, Penn State is also doing on its 900 buildings state wide.

PSU is an institution that has been around since 1855 and just as UMB has to deal will old and outdated building systems so does PSU. This leads to large scale retrofitting and a program named Guaranteed Energy Savings Program. This program develops projects for the university to implement on various buildings throughout the campus and branch campuses. Penn State's Office of Physical Plant (OPP) employs Energy Program Engineers who identify buildings through analysis and monitoring within the campus where the "environmental initiatives of the University can be applied." This often takes the form of Energy Conservation Measures (ECMs). These measures are the retrofitting solutions that can be performed on a large scale and show relatively quick payback periods. These solutions, according to the OPP website are:

- Steam Traps
- Low-flow water fixtures
- High-efficiency lighting and ballasts
- Chiller/Chilled Water upgrades
- Programmable Thermostats
- Reprogramming or upgrading control systems
- System/Equipment tune ups
- Fuel selection/switching
- Water Treatment
- Cleaning/flushing HVAC piping

These solutions are packaged into projects that aim to tackle an area of campus by a particular date. Some of the past completed projects include:

- UP - Initial Project Phase I
- UP - Initial Project Phase II
- UP -West Halls

Below are some charts reproduced from the OPP website that show how the Initial Project Phase I was packaged and the savings that have resulted since.

Buildings Included in Phase I	
Atherton	Arts
Ceramics	Computer
Frear South	Mateer
Materials Research Lab	Mueller
Music	Noll
Osmond	Pattee/Paterno Library
Pond	Porter
Shunk	

Figure 2.4 GESP project buildings Phase 1

The emphasis of Phase I was lighting upgrades, water retrofits and steam trap replacements. The initial cost was $2,212,937 and in 2002 avoided the costs and emissions below.

Energy Savings (avoided energy in 2002)		
Commodity	**Savings**	**Avoided Cost**
Electric	2.89M kWh	$127,403
Water	5.36M gallons	$31,933
Steam	5.88M pounds	$71,079

Figure 2.5 Phase 1 avoided energy in 2002

Avoided Emissions

Type	**Amount**
CO_2	1959 tons
NO_x	5 tons
SO_x	15 tons
CO	291 lbs
PM	587 lbs
VOCs	57 lbs

Figure 2.6 Phase 1 avoided emissions

Another continuing theme is the need to have a centralized command center to collect and react to data provided by the buildings on campus. Penn State's version of this is called Enterprise Utility Management Solution (EUMS). PSU has teamed up with Johnson Controls to develop this tool that will improve operational efficiency as well as enable PSU to purchase the least amount of energy necessary. In the EUMS document it is described as,

"Defined at simplest level, an EUMS consolidates all energy related data (sources, costs, control, and monitoring points) into a data warehouse and provides tools to access and truly interact with the data."

Although it may sound simple it is very broad in scope. Not just a building automation system, EUMS provides "data collection, data access, diagnostic and monitoring capabilities." It also links billing and metering information to operational data. A common data center attached to a building's systems is shown below.

Figure 2.7 Typical automation

Together this data takes the form of diagnostics, analyses, and monitoring so action can be taken immediately in response to the information provided. It truly is a proactive system. The basic schematic of the system is shown on the next page.

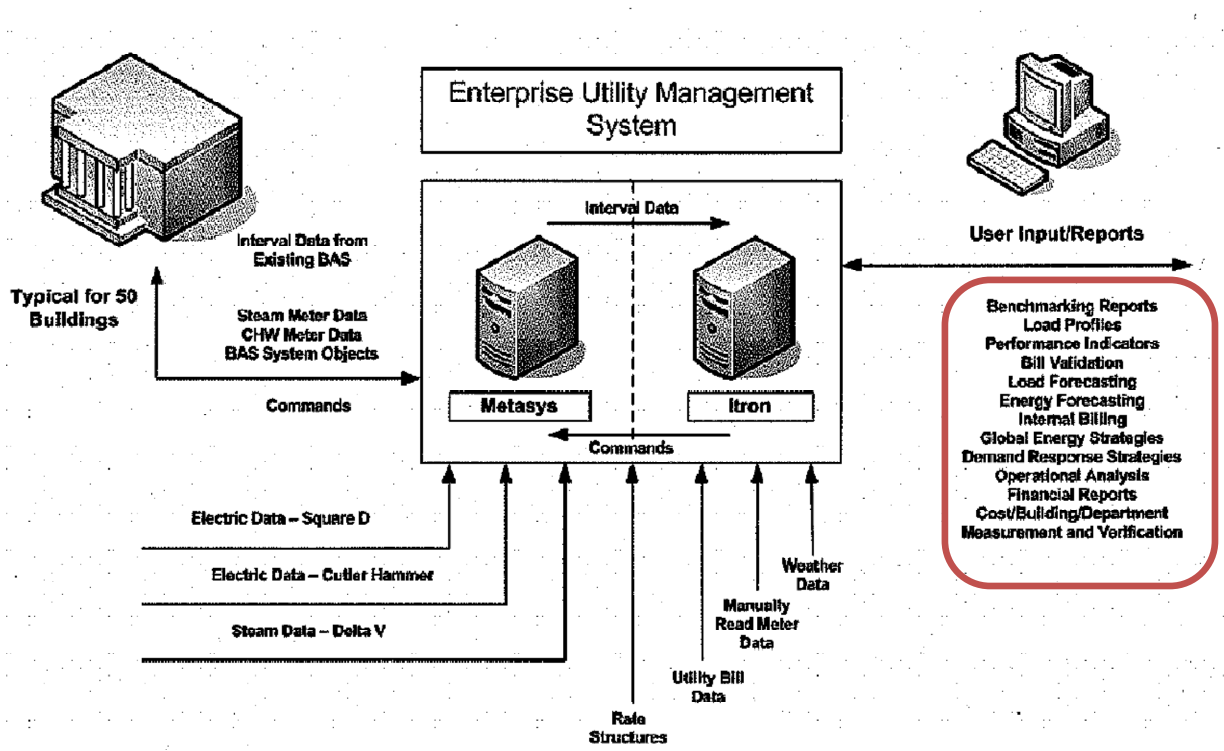


Figure 2.7 EUMS Schematic

Circled are all the in depth reports that will be available at the fingertips of the facility management team so quick and energy saving responses can be made. PSU predicts rapid returns in the form of:

- Providing a positive cash flow
- Lowering operational costs
- More effectively deploying staff through improved processes
- Reducing equipment maintenance costs and increasing equipment life
- Improving the efficiency of energy purchasing

One thing mentioned above that is particularly interesting is the deployment of staff. There are many saving opportunities when you can be sure your workforce is where it needs to be. EUMS will provide alerts when building system needs attention. Because the alerts arrive instantly, the staff can determine if the building will correct the issue on its own, if it can be corrected from the command center, or if it truly is necessary for maintenance to assess the problem on-site.

When a system is designed for a building it does not automatically work as it designed. This is not a result of poor design (although it can be) but the result of every building being unique. Predicting exactly how it will work is like choosing the winning lottery numbers. Now the odds aren't as bad as the lottery but the point is that for building systems to work as they are designed they need analysis post-construction and then adjustments must be made accordingly.

This is the job of the final Penn State program that will be explained, Penn State's Continuous Commissioning Program (CCx). Developed in 1998 this program monitors system functionality as well as checks if everything is installed properly and to the standards of PSU. The Commissioning Plan's goals are as follows:

- Optimize the operation of existing systems
- Improve building comfort within the capabilities of the installed system
- Reduce energy cost
- Solve indoor air quality problems
- Guarantee continuous optimal operation for years to come
- Reduce operational and maintenance costs

This is done by rigorous investigation of the mechanical systems and ongoing monitoring of system operation. Below is a portion of an Air Handling Unit commissioning checklist that was downloaded from the OPP website.

Check If Okay/Note if Deficient	Equipment Tags					
Cabinet and General Installation	**AHU1**	**AHU2**	**AHU3**	**AHU4**	**AHU5**	**AHU6**
Casing condition good: no dents, leaks, door gaskets installed						
Access doors close tightly - no leaks						
Boot between duct and unit tight and in good condition						
Vibration isolation equipment installed & released from shipping locks						
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc)						
Filters installed and replacement type and efficiency permanently affixed to housing--construction filters removed						
Notes:						

Figure 2.8 Commissioning checklist for AHU

As it is seen the checklist is very thorough and covers any item that could potentially weaken the systems efficiency.

Just like GESP the CCx develops projects that package areas of campuses together to systematically check every building. As of today these projects have commissioned almost 60 buildings on campus.

Penn State also attacks energy from a new construction standpoint. The current standard for Green Construction is LEED (Leadership in Energy and Environmental Design). This standard, developed by the USGBC, makes the builder consider the entire construction process from precon to post construction, from on site recycling to the HVAC efficiency. Penn State has completed three buildings that have achieved this certification with the Stuckeman Family Building achieving the highest level, gold. Now all buildings constructed on campus must achieve at least LEED certified. PSU also has a great deal of documentation explaining exactly which points they want to go for when achieving LEED certification.

Penn State is no stranger to energy conservation efforts. The programs described above are major undertakings and show Penn State University's long term commitment to cutting the energy consumption of the 900 buildings and 7,300 acres of campus.

2.7 Los Angeles Community College District

The LACCD encompasses nine colleges and roughly 200,000 students. Being so numerous, together they face the same issues of larger, 4 year universities. This district is extremely ambitious, in a good way. They have the "largest public sector sustainable building effort in the US," and hope to achieve their goal of "off the grid" by constructing 90 LEED certified buildings, using renewable energy, conservation strategies and develop education programs to create "conservant architects, engineers, and contractors," according to the LACCD website. Like UMB, LACCD has signed the American College and University Presidents Climate Committee. Below is the location map of all nine schools and their physical relationship to each other.

Figure 2.9 Map of Los Angeles Community College District

LACCD's plan to be off the grid (no outside energy) has 4 main points of attack (reproduced from the LACCD S Energy Strategic Plan):

- Efficient Renewable Energy Central Plants
- Demand Management Through Performance Contracts
- One MW Solar/PV per campus
- Sustainable Curriculum Program

There are many similarities between this plan and the plans of the previous universities.

Setting up a central plant between buildings has proven to be a vital initial strategy for any university's conservation plan. LACCD is in the process of constructing 1 central high efficiency sustainable source for hot and chilled water. It will be design to meet the current and future needs of the college. This will, as with the others, provide a plant that yields great efficiency since it only produces and uses the required energy. Some of the features contained in this plant will be:

- Solar Heat Tubes
- Absorption Chillers
- Thermal Storage – Ice
- Co-Generation – Electricity and Heat
- Hot water Boiler/Heater

Much of the funding will come from the private sector and the "Foundation for California Community Colleges," which receives the lowest funding of colleges in the state.

Performance contracting is needed to assess the energy consumption of buildings that already exist. The analyses that result are used to determine the most effective approaches and retrofits for the college. LACCD utilizes the national program, Energy Services Company (ESCO). They perform the analysis and then make cost and savings analyses of different Energy Conservation Measures (ECM) to determine which are the most beneficial. Penn State's program GESP is exactly the same accept the analyses and cost comparisons are done in house as compared to contracted. As a part of this plan LACCD will install the following features on all existing and future projects:

- High Efficiency Insulation
- Low-E Glazing
- White Roof
- Green Roof
- Metering and Monitoring Systems

One of the more cutting edge techniques that LACCD is striving towards is installing a Megawatt Solar/PV system on every campus. LA receives large amounts of sun and the location of the colleges does not limit the panels to high elevation installation.

Many of the systems will be in the form of large canopies above existing parking lots, like the ones shown below.

Figure 2.10 LACCD solar car ports

Solar panels will also be used to harvest the sun for renewable hot water. Initially a private firm will install the system and sell the electricity to the college. Eventually the college will buy out the systems.

LACCD also has an extensive awareness plan. It is called the Sustainable Development Curriculum and plans to educate by:

- Courses as certified, licenses and advanced degrees
- Training for jobs, companies and advanced degrees
- Collaboration with unions, private businesses, public, government and non-profit sectors
- Hands on experience with on campus building programs
- Curriculum such as solar, wind, geothermal, hybrid technologies, economics, life-cycle accounting and operations and maintenance
- Impact on climate change (large amounts of material already available)

A goal to be completely removed from the energy grid requires every aspect in the life energy and buildings to be considered. The plan must be thorough and account for the present and future. The Los Angeles Community College District has done just this with their plan that is in place and will reap the benefits of one day being completely off the energy grid.

2.8 Conclusion

The above discussed a lot of different programs set in place at different universities but within these programs are essential similarities that must be contained in any college's conservation plan. Universities need to think of the buildings that make up the campus as one. No building should be "left on an island" because the buildings that are will be the ones that use the most energy and can negate improvements to the others. All buildings must be analyzed, new or old, and this analyzation and monitoring cannot be a one time event. These programs have to be continuous and evolving if they are ever to work and take control of the energy problems facing the world. Finally, universities must educate. Learning is the first step but these universities understand that there is no good in knowledge if it is not accessible and passed along to everyone. Because, just like there can be no building on an island, there can be no person on an island. We all have a part to play if the significant efforts, being taken by many, are going to have the impact they need.

3.0 Building Envelope and Space Heating Analysis – Depth and Mechanical Breadth Included

3.1 Problem

Continuing with the theme of energy conservation, analysis will be done to explore ways to conserve energy on the University of Maryland, Baltimore New Administration Building. Energy conservation can take the form of alternative materials, new construction processes, more efficient equipment, etc. Heating and cooling a space uses a considerable amount of energy. Analyzing the factors that go into heating and cooling a space can drastically improve the buildings energy efficiency. Often times this analysis will lead to changes in the building envelope because it can have significant effects on the conditioning of a space.

Another major aspect of heating spaces around the perimeter is finned tube radiant heaters. These are common in most buildings, found underneath windows. They can be wasteful, in regards to energy, and designing alternative ways to heat a space may be beneficial.

3.2 Background

The UMB New Administration building utilizes two main façade types, red brick with punch windows and curtain wall. The curtain wall is 878 SF and is located on the South (main) entrance of the building. The entrance leads into a large, 2 story high lobby area. The rest of the building is red brick with 13,000+ SF of punch windows. Since the curtain wall is a small percentage of the overall façade, its envelope characteristics will be unchanged. The focus of this analysis will be on the red brick portion of the building façade.

Analysis will be done to determine the current state of the envelope's efficiency. Once the initial analysis is completed, different aspects of the envelope will be altered in hopes to yield better energy efficiency. Since windows account for close to 40% of the entire building's façade, glazing with better thermal properties will be investigated to see if the energy saved equates to the inherent price increase of better glazing.

Also, underneath each window is a finned tube heater that is connected to a hot water loop that circulates throughout the building. These heaters are typically present to account for the heat that is lost through the windows. They themselves tend to waste significant quantities of energy and because of this mechanical engineers look for ways to remove these heaters.

3.3 Goal

The goal of this analysis is to reduce the energy usage of the UMB New Administration Building by improving its envelope and researching the feasibility and effects of eliminating the perimeter heaters under each window. It will also attempt to limit the negative effects in regards to project cost, schedule and constructability, which may result from these changes.

3.4 Methodology

1. Determine the overall U-value of the present wall assembly.

2. Research different ways or alternative materials to improve this U-value without improving the thickness of the assembly.

3. Research glazing that offers improved thermal qualities while complying with specifications already in place.

4. Create a new assembly that yields the lowest U-value in the given space.

5. Create a building model in “eQuest” to estimate the annual energy consumption of the current building and the consumption with the proposed changes taken into account.

6. Consult with mechanical engineers to determine what can be done to allow the removal of the perimeter heating.

7. Analyze all the results and their effect on the project’s initial and long term costs, schedule and constructability.

8. Conclude and recommend a combination of alternatives that work best.

3.5 Building Envelope Improvements

3.5.1 Wall Assembly

Keeping the wall thickness the same while still improving the overall U-value was the main focus of this process. U-value is the reciprocal of the R-value which is the resistance of a material to heat transfer. To improve the U-value 2 steps were taken. The first was increasing the 1” rigid insulation that was already present in the wall to 2”. The addition of this 1” will only have an effect on the air space within the wall. It will go from a 2” air space to a 1” air space. This is a small change that doubles the R-value of the insulation from 5 to 10. The second involves the batt insulation. The batt insulation utilized on the UMB New Administration Building is 6 ¼” fiberglass with an R-value of 19. Insulation does not retain its R-value if it is compressed into a smaller space than its own thickness. For a typical 2x6 stud the insulation is compressed into a 5 ½” space. This compression reduces the R-value to 15. For this reason the second improvement to the envelope was replacing the 6 ¼”, R-19 insulation with 5 ½”, high density R-21 insulation. This high density alternative allows the insulation to fit precisely into the space without losing any thermal resistance.

3.5.2 Glazing

The current glazing utilized on the UMB Administration Building is clear, insulating, double paned and has a ½" air space. The thermal characteristics of these windows are respectable with a U-value of .41 in the winter and .39 in the summer, a shading coefficient (SC) of .42, and a visible transmittance of 43%. To improve these numbers different tints, coatings, and air filled spaces were explored. Triple pained alternatives were not investigated since they would require different and larger frames, thus affecting the walls thickness. It was narrowed down to two options which are both variations of Viracon's VUE-50 series. They both are insulating, double paned with a ½" argon filled space and yield a U-value of .2 in the summer and .25 in the winter. The only difference is that one is clear coated and the other has a grey tint. This gives the grey tinted glass a SC of .19 and a visible transmittance of 24% while the clear has a SC of .29 and a visible transmittance of 49%. Shading coefficients have a large impact on the summer cooling of the building since they block radiance from the sun and U-values are important all year around since they resist the transfer of heat from outside to inside and vice versa.

3.5.3 Elimination of Perimeter Heating

Space heating in the UMB New Administration Building consists of VAV hot water reheats and 219 (3437 LF) perimeter finned tube radiant heaters. Together they supply comfort to the room and makeup for lost heat through the building envelope. As mentioned, finned tube heaters require a lot of energy to produce heat, much of which is lost through the fenestration of the building. Making buildings more efficient often involves attempts to design a space that no longer needs the finned tube heaters. The heat that is removed can be supplied by the VAV reheat boxes already present or in some cases can be conserved with a high efficient building envelope (typically involving triple paned glazing). After consultation with several mechanical engineers it was concluded that the finned tube heaters could be removed without any other action. The engineers agreed that because of the uniformity of the building and assuming the VAV hot water reheats are properly sized, the baseboard heaters could be eliminated. The VAV's are assumed to provide all the necessary space heating. There are many positive implications resulting from this change that will be discussed later.

3.6 Thermal Analysis – Mechanical Breadth

Once the decisions were made on materials and/or equipment that would be added (or subtracted) three things were done to perform load calculations. The first was to develop and overall U-value for the different wall assemblies, derived from the various R-values. On the next page is a table that breaks down the current wall assembly as well as the proposed assembly. The materials altered are those that are highlighted.

	Existing Wall Assembly			Proposed Wall Assembly		
	Wall Construction	Thickness	R-Value (ft^2 ·°F·hr/BTU)	Wall Construction	Thickness	R-Value (ft^2 ·°F·hr/BTU)
	Brick Veneer	4"	0.44	Brick Veneer	4"	0.44
	Air Space	2"	1	**Air Space**	1"	0.5
	Rigid Insulation (EPS)	1"	5	**Rigid Insulation (EPS)**	2"	10
	Air Infiltration Barrier	-	-	Air Infiltration Barrier	-	-
	Exterior Sheathing	5/8"	0.77	Exterior Sheathing	5/8"	0.77
	R-19 Batt Insulation	6.25"	17	**R-21 Batt Insulation**	5.5"	21
	Gypsum Board	5/8"	0.56	Gypsum Board	5/8"	0.56
	Total	13.75"	24.77	**Total**	13.75"	33.27
		U-Value (BTU/ft^2·°F·hr) = 0.040			**U-Value (BTU/ft^2·°F·hr) = 0.030**	

Table 3.1 Wall assembly comparison

As it is shown above these improvements do not increase the thickness of the wall and reduce the overall U-value from 0.044 to 0.030 (BTU/ft^2·°F·hr). This may not sound like a lot but over the course of a heating and cooling season it can add up considerably. Keep in mind that, as mentioned before, the R-19 batt insulation R-value is reduced to 15 on account of compression into the space.

Below is a quick comparison of the three types of windows as well as U-values of systems that will remain unchanged.

	Existing Windows	Proposed Clear Windows	Proposed Grey Windows
U-value			
Winter	0.41	0.25	0.25
Summer	0.39	0.2	0.2
Shading Coefficient	0.44	0.29	0.19

	U-Value
Roof	0.033
Curtainwall	0.66

Table 3.2 Thermal characteristics of windows, roof and curtainwall.

The second was to use the Degree Day method to get a rough estimation of the annual loads facing this building. On the next page are the preliminary estimates using Degree Days converted into Degree Hours.

	Baseline Building	Building 1
Description	This is the building that was constructed	This is the Baseline Building with additional rigid insulation and the R-21 batt
Annual Energy Load (BTU)	1,147,215,002	1,080,203,845

	Baseline Building	Building 2	Building 3
Description	This is the building that was constructed	This is the Baseline Building with Viracon's VUE-50 series CLEAR	This is the Baseline Building with Viracon's VUE-50 series GREY
Annual Energy Load (BTU)	1,147,215,002	845,435,775	845,435,775

	Baseline Building	Building 4	Building 5
Description	This is the building that was constructed	This is the combination of Building 1 and 2	This is the combination of Building 1 and 3
Annual Energy Load (BTU)	1,147,215,002	778,424,519	778,424,519

Table 3.3 Annual energy load using degree day method

As it is shown the Degree Day method estimates the annual load on the building to be 1,147,215,002 BTU. By replacing the windows and adding insulation the usage drops to 778,424,519 BTUs, which is a decrease of 368,790,483 BTUs. While this is a decent rough estimate, it does leave out a few important elements. The degree day method only considers the U-value of the material and so characteristics, like the shading coefficient, are neglected. The fact that Building 2 and 3 have the same loads but different properties shows this effect. Other elements like energy used to run equipment, lighting and occupancy are also not taken into account. For this reason further analysis must be done. The Degree Day numbers are not used past this point. To see Degree Day information see Appendix C.

The third step utilized eQuest, a building energy use analysis tool that is used by many professionals in industry. Multiple models for the different building scenarios (same as above) were created in eQuest and then simulations compared each of their annual energy usage. These comparisons were used to determine the effectiveness of the proposed changes. This provides a much more in depth and accurate analysis because eQuest requires roughly 40 data inputs relative to the building. This is virtually the only way to predict HVAC equipment because the level of operation varies considerably throughout a year, a month and even throughout the day.

The base model of the existing model was created and then a model containing each change (insulation, window type, removing finned tube heater) was also created. Each was compared individually to the base building and then finally combined to determine the best combination. Below there will be a series of charts that clearly show these comparisons. The following key will aid in reading the charts.

KEY		
	Baseline Building - This is the building that was constructed	
Building A - This is the Baseline Building with additional rigid insulation and the R-21 batt	**Building C** - This is the Baseline Building with Viracon's VUE-50 series GREY	**Building E** - This is the combination of Building A, B and D
Building B - This is the Baseline Building with Viracon's VUE-50 series CLEAR	**Building D** - This is the Baseline Building without finned tube heaters	**Building F** - This is the combination of Building A, C and D

Table 3.4 Building key

The first comparison was performed to analyze the annual energy difference between the Base Building and Building A (change in insulation). Electric consumption is now estimated since eQuest required inputs such as equipment, lighting, etc.

INSULATION ANALYSYS

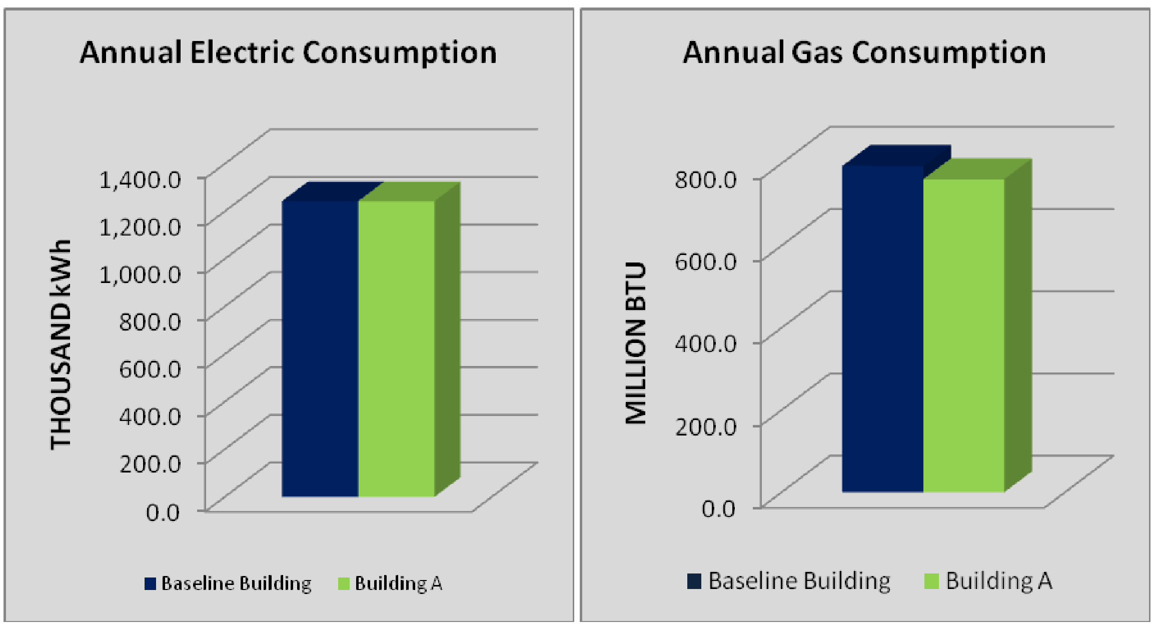


Figure 3.1 Annual electric and gas consumption for Baseline Building and Building A

This analysis showed that there would be no impact on the electrical consumption due to the added insulation but that Building A would save 32.07 million BTUs (about 4%) annually.

As mentioned before envelope improvements make conditioning a space more efficient and that is exactly where these savings have come from. The entire savings came from less gas being used to generate hot water for space heating. The graph on the next page displays these savings (32.07 million BTUs, 4%).

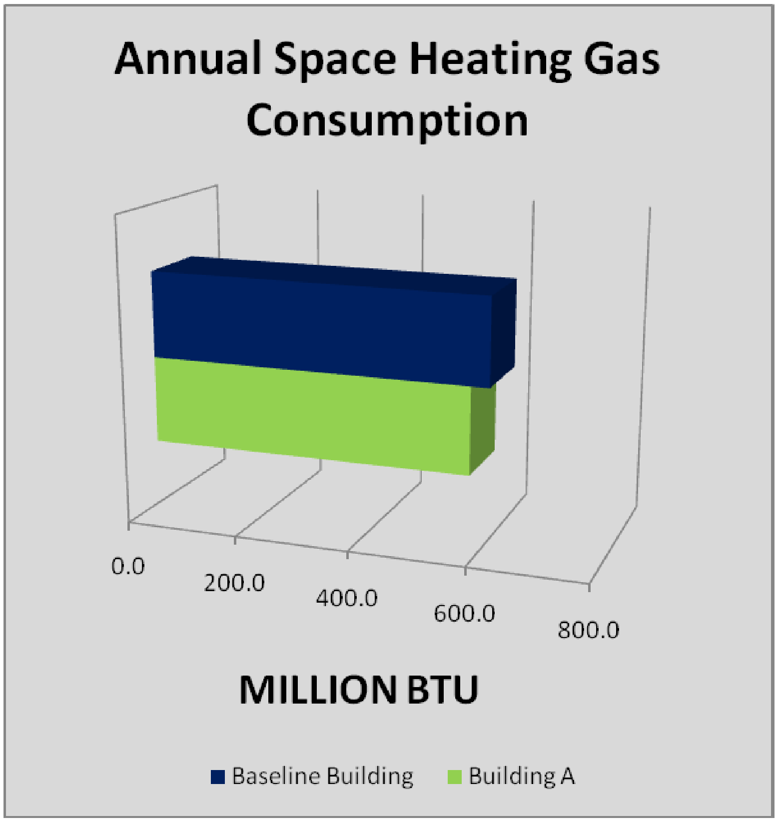
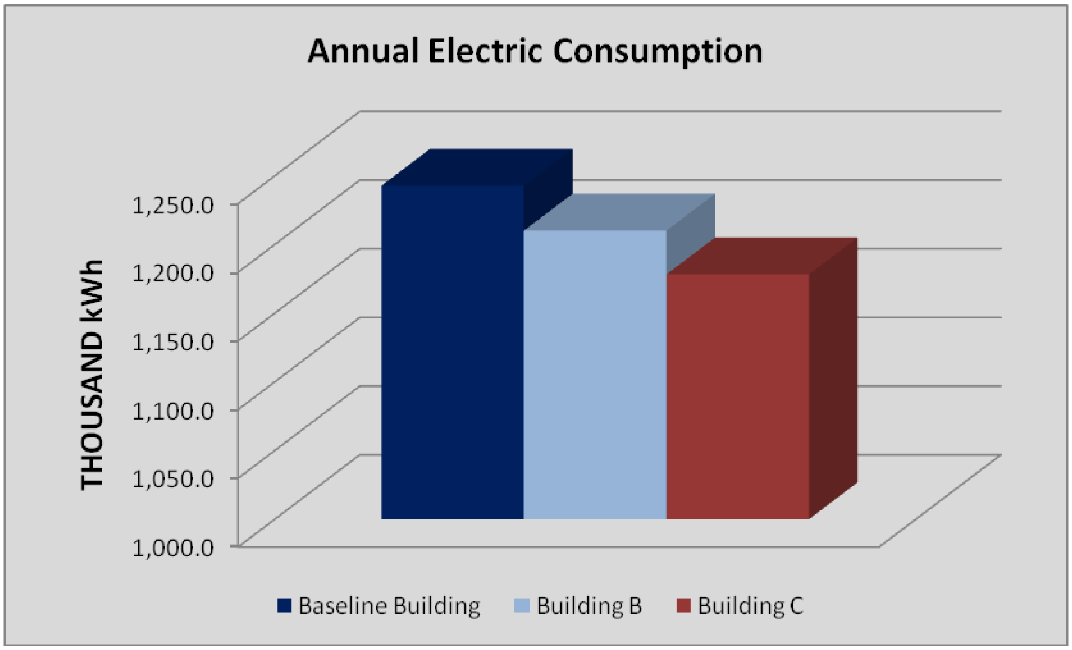


Figure 3.2 Space heating comparison for Baseline Building and Building A

Tables that show the effect on space heating for all the alternatives can be found in Appendix D.

The next set of graphs compare the three different window types (existing and Viracon VUE-50 clear coated and grey) and their effect on the annual energy consumption.



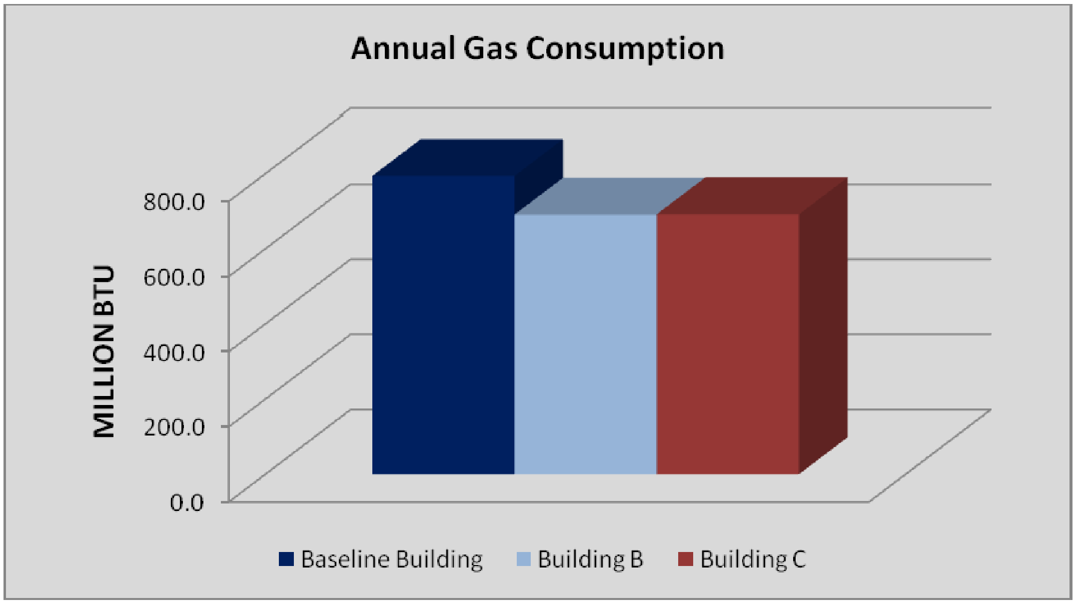


Figure 3.3 Annual electric and gas consumption for Baseline Building, Building B and Building C

There are large electrical consumption differences between all three types of glass. This makes sense because the shading coefficient gets progressively lower as you move from left to right. A lower SC blocks more of the suns radiation and therefore the space requires less cooling and thus less electricity. Building B saves 32.7 thousand kWh per year while Building C saves 64.6 thousand kWh.

The two alternative windows have the same U-values and so they decrease gas consumption almost equally. Building B saves an annual 102.9 million BTUs (13%) while Building C saves an annual 101.9 million BTUs (12.8%), a difference of 1 million BTUs (.2%). For the same reason that Building C saved more electricity than Building B, the reverse is true for gas consumption. Building C, with a lower SC lets less solar radiation in during the winter months and as a result the space needs more heating.

The third comparison dealt with eliminating the perimeter heating in the Baseline building and how this change would affect annual energy usage.

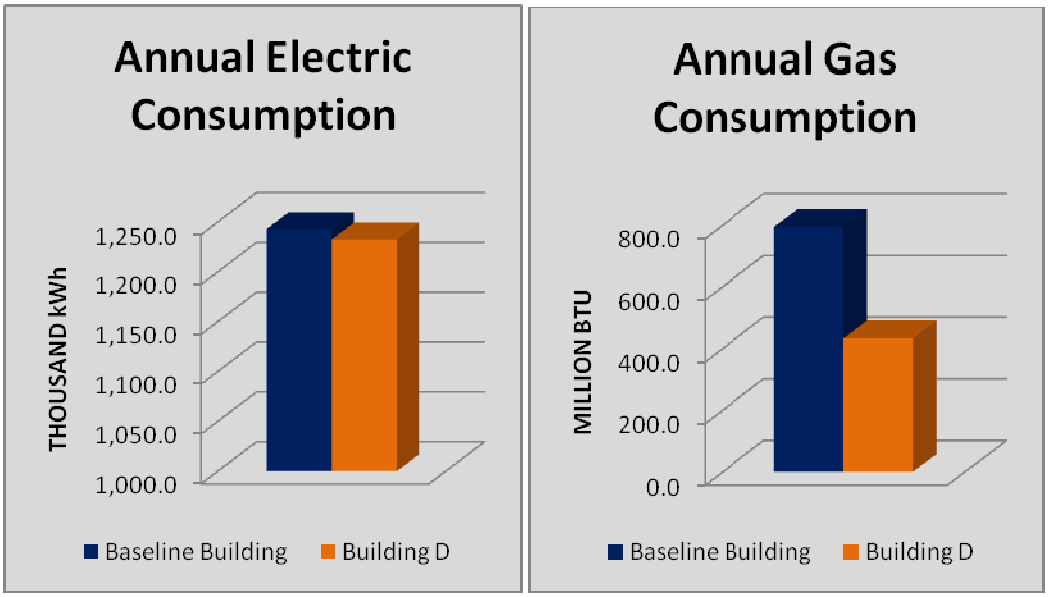
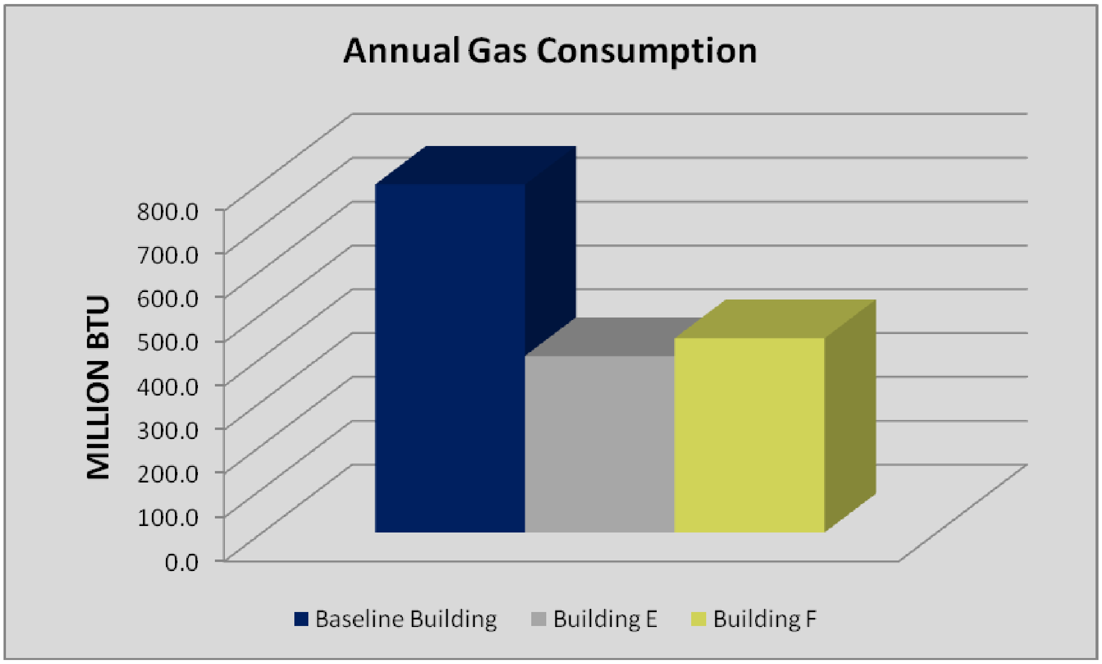


Figure 3.4 Annual electric and gas consumption for Baseline Building and Building D

The analysis that was done shows that removing the perimeter heating actually saves gas and electricity. Eliminating the finned tube heaters saves about 10.5 thousand kWh (1%) and 361.1 million BTUs (45%) annually. This does make sense because much of the heat that was being produced by the heater would escape through the window. Now, heat is not being pumped directly in front of the window so less energy is needed to maintain the same comfort. Heat is still being supplied to these spaces because as mentioned they contain the VAV reheat terminals.

Finally, analyses were done using combinations of the previous alternatives. Both the insulation improvement and the removal of the finned tube heaters proved to be beneficial to making the building more efficient. This only leaves the question of which windows will be more efficient. The graphs below compare the Baseline Building and two other buildings. Building E and F both have had the baseboard heating eliminated and insulation added. The only difference is Building E has Viracon's VUE-50 series clear glazing and the other has the grey.



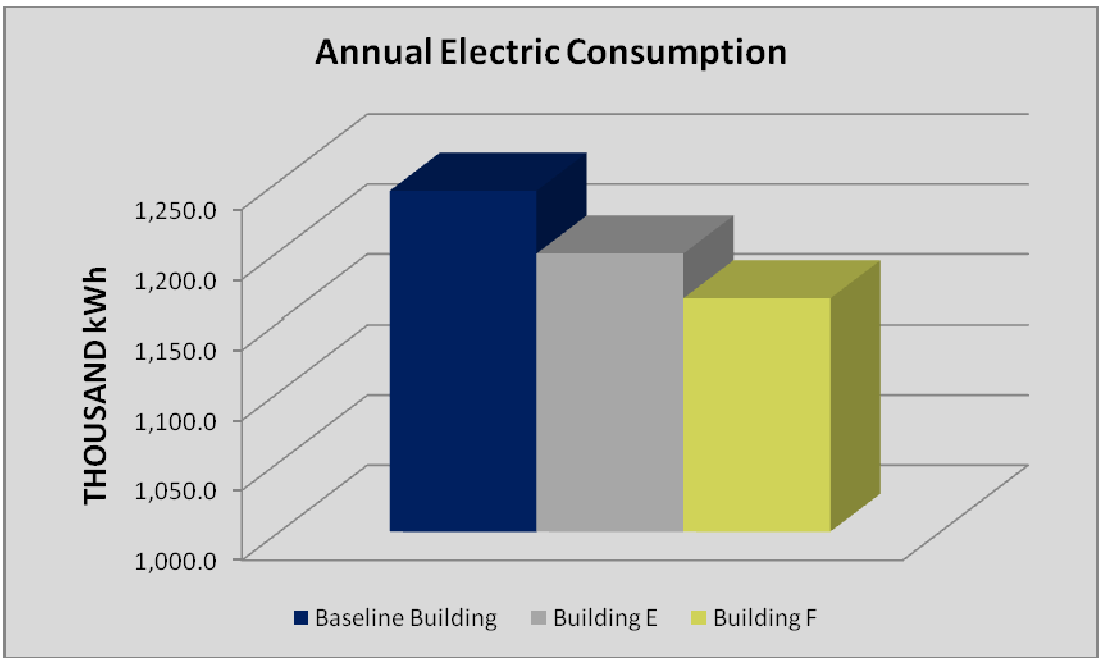


Figure 3.5 Annual electric and gas consumption for Baseline Building, Building E and Building F

As expected the annual electric and gas consumption of the two scenarios are less then the Baseline Building. Again, it is seen that electric consumption falls progressively and that gas consumption is effected by the different SCs of the glazing. Both buildings have considerable savings. On the next page are the compiled energy savings.

	Baseline Building	Building E	Building F
Annual Electric Consumption (kWh)	1,242.9	1,198.0	1,166.0
Annual Electric Savings	-	**44.9**	**76.9**
Percent	-	**3.6%**	**6.2%**
Annual Gas Consumption (BTU)	793.7	402.6	443.4
Annual Gas Savings	-	**391.1**	**350.3**
Percent	-	**49.3%**	**44.1%**

Table 3.5 Annual electric and gas consumption savings for Baseline Building, Building E and Building F

The numbers are very close and the best combination for this situation will be determined by the cost savings and the owner's preference.

3.7 Cost Implications

The ultimate decider of which option will prove to be most beneficial will depend on cost information. Estimates were made to determine the changes in cost that would result from the different alternatives that were proposed above. Finally these estimates will be compared to the utility savings that will result.

Below are the price comparisons of the different insulations. The actual unit cost of the existing insulation was provided by Barton Malow and then RSMeans was used to estimate the additional costs. The location factor for Division 07 Thermal and Moisture Protection for Baltimore, MD is 97.6. Below is a table showing the price increase due to insulation improvements.

	RSMeans (/SF)	Actual (/SF)	ft²	Location Factor	Extension	Price Increase
1" Rigid (EPS)	-	$2.10	35,399	-	$74,338	-
2" Rigid (EPS)	$2.55	-	35,399	97.6	$88,101	$13,763
	RSMeans (/SF)	**Actual (/SF)**	**ft²**	**Location Factor**	**Extension**	**Price Increase**
R-19 Batt	-	$1.20	35,399	-	$42,479	-
R-21 Batt	$1.50	-	35,399	97.6	$51,824	$9,345
					Total Price Increase	**$23,108**

Table 3.6 Price increase of insulation improvements

As the table shows above, this additional insulation would add a cost of $23,108. Even though this may be small price on a $30 million project this extra cost must be justified by the annual energy savings to be worth while.

Accurate enough glazing prices were not easily available so RSMeans was used for this entire analysis. The location factor for Division 08 Openings in Baltimore, MD is 93.7.

Below is a table showing the price increase due to window improvements.

	RSMeans (/SF)	ft²	Location Factor	Extension	Price Increase
1" Clear	**$38.00**	**13,949**	-	$530,062.00	-
Viracon Clear	$46.00	13,949	93.7	$601,229.80	$71,167.80
Viracon Grey	**$48.00**	13,949	93.7	$627,370.22	$97,308.22

Table 3.7 Price increase of window improvements

Improving the glazing is where the biggest increase in cost stems from so again it must be made up in a reasonable amount of time in energy savings.

As discussed before, consultations with mechanical engineers concluded that the perimeter heating could be removed without taken any further action. This means that all the material and labor will be considered savings. All labor wages were estimated using RSMeans. Installation durations were determined using the job schedule and are explained later. Below is a table showing the cost savings of removing perimeter heaters.

	Actual (/LF)	LNFT	Extension
Finned Tube Radiator	$70.00	3,437	**$240,590**
.75" Copper Pipe	$15.98	6,900	**$110,262**

	Amount of Work (LF)	Durations (Days)	Crew Size	Combined Wage (/day)	Total Savings
Fin Tube Radiation Piping	6900	48	4	$1,051.20	**$50,457.60**
Set/Connect Fin Tube Heater	3437	52	2	$525.60	**$27,331.20**

Total Savings	**$428,641.00**

Table 3.8 Savings due to removing perimeter heaters

These savings instantly account for any additional costs incurred from the other envelope improvements. This allows for an initial job cost savings as well the annual energy savings to be profited right away. There is no need for a life-cycle or payback period.

The last element of cost to consider is annual energy costs. Energy costs were calculated by taking the eQuest annual energy estimation and applying average energy costs seen in Baltimore, MD in 2008. In 2008 the average electric cost was $.1282/kWh and gas was $12.96/1000CF. The BTU output that was created by eQuest was converted to CF by dividing BTU by 1030 (1CF≈1030BTU). Below is a table showing the energy and material savings due to alternatives.

	Price	Demand	Total Cost	Annual Savings
	Electric (/kWh)	kWh	Total Cost	Savings
Baseline Building	$0.1282	1,242,900	$159,340	-
Building E	$0.1282	1,198,000	$153,584	**$5,756**
Building F	$0.1282	1,166,000	$149,481	**$9,859**
	Gas (/1000CF)	CF	Total Cost	Savings
Baseline Building	$12.96	770,572.82	$9,987	-
Building E	$12.96	390,902.91	$5,066	**$4,921**
Building F	$12.96	430,466.02	$5,579	**$4,408**

Table 3.9 Energy savings

	Total Material Cost	Total Material Savings	Total Installation Savings	Total Annual Energy Savings	Final Savings
Building E	$94,276	$350,852	**$77,789**	$10,677	**$345,042**
Building F	$120,416	$350,852	**$77,789**	$14,266	**$322,491**

Table 3.10 Comparison of total savings between Building E and Building F

So, after all things have been considered, Building E has the greatest initial savings, a difference of $26,140, and Building F's greater annual savings would take approximately 7.5 years to account for this difference in initial savings. This is shown graphically, on the next page, with Building E beginning at $26,140 and Building F on $0. After that the annual energy savings are simply added each year.

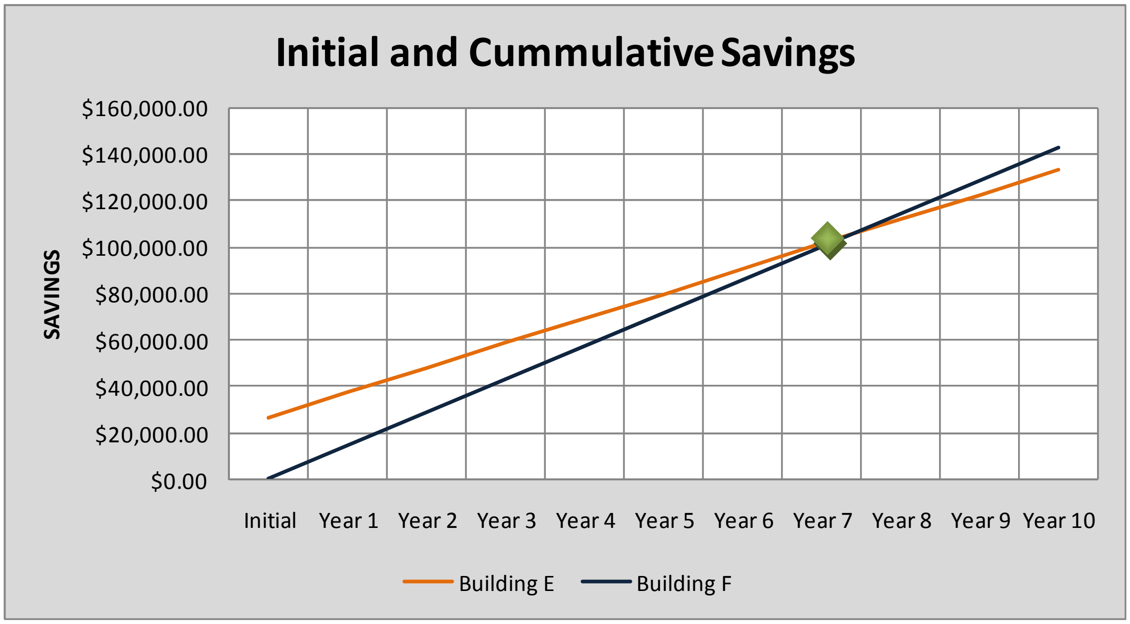


Figure 3.6 Graph of time it would take for savings in Building F to equal Building E

There is no bad decision. Each scenario saves money, it just depends on the owner's preference and financial state, whether they want to wait longer for the same return.

3.8 Schedule and Constructability Implications

With any alternative there may result schedule delays or constructability issues. The previously described materials were specifically chosen so they would have no such issues. The insulation that was chosen does not increase the wall assembly width so no action has to be taken such as widening the foundation wall or losing usable interior space. Both window replacement options are the same width and thickness of the ones that were installed so the same frames that were specified can still be used. The only effect seen on the schedule is time that will be saved by removing the perimeter heating.

There were two things to consider when estimating the time saved on the schedule from eliminating the perimeter heaters: copper piping and the radiators themselves. The copper piping for the finned tube heaters is branched off of the copper piping for the main hot water loop. This loop supplies the hot water to the perimeter heating as well as the VAV reheat terminals. On the schedule these are both grouped together as "HVAC PIPING LOOP – MAINS & BRANCHES". This makes estimating the length of time required to run the piping for only the finned tube heaters more challenging. Installation of the heaters is explicitly labeled which, makes estimation easier.

The two line items as they appear on the schedule that deal with perimeter heating are as follows:

	Amount of Work (LF)	Total Days Required
HVAC PIPING LOOP - MAINS & BRANCHES	-	80
SET/CONNECT FIN TUBE HEATER	3437	52

Table 3.11 Durations of HVAC copper piping and finned tube installation

To estimate how many days out of the 80 given for HVAC piping it takes to run the baseboard copper piping a rough LF estimate was done on a typical floor of the building. It was concluded that the branches related to perimeter heating account for approximately 60% of the copper piping. For this reason 60% of the 80 days, 48, was allotted to the finned tube heater branches. The chart below shows the amount of days that will be saved on the schedule because of the perimeter heating elimination.

	Amount of Work (LF)	Durations (Days)
Fin Tube Radiation Piping	6900	48
Set/Connect Fin Tube Heater	3437	52

Table 3.12 Durations for finned tube copper piping and installation

None of these days are directly linked to the critical path but as mentioned above this saves money as well.

3.9 Conclusion and Recommendation

In conclusion after exploring all the possible results of the various alternatives, it is shown that the changes are beneficial and would prove to enhance the building's efficiency. The combination of added insulation, eliminated perimeter heaters, and Viracon's VUE-50 Clear (Building E) is recommended. Its initial savings is better and even after 7.5 years when Building F begins saving more money than Building E it is not enough to pay the higher upfront cost. Also with Building E, the glass is clear, which was the owner's choice from the beginning and that ultimately is the most important element.

4.0 Photovoltaic Implementation

4.1 Problem

With energy prices rising everyday and the economy continuing to fall a growing trend is renewable energy. Renewables mean exactly how they sound, if it can be produced and used over and over. One trend that has been around for ages but is gaining lots of steam lately is photovoltaic energy and if done correctly can create significant savings on an energy bill.

4.2 Background

UMB is currently making major strides in energy efficiency by retro fitting existing buildings with up to date technologies such as building automations. The approach of this analysis is supposing that UMB wants to further its energy strides utilizing photovoltaics, starting with the New Administration Building. So, this requires an investigation on the feasibility and logics of a photovoltaic system implementation.

4.3 Goal

The goal of this analysis is to design a photovoltaic system that will be efficient and yield a savings after a short payback period. It also needs to be presented in a way that would make an owner believe in its practical application.

4.4 Methodology

1. Perform a preliminary site analysis and choose the optimum location for the system.

2. Choose system size and manufacturer.

3. Design system configuration (mounting system, array angle, spacial arrangement, series connections).

4. Determine energy savings and payback period.

6. Analyze all the results and their effect on the project's initial and long term costs, schedule and constructability.

7. Conclude and make a recommendation.

4.5 Photovoltaic System

4.5.1 Location

Implementing photovoltaics on a city building can be a difficult task. Cities have multiple large buildings so unless the building in question is tall enough by itself or by adding a structure above the system will encounter shadows from surrounding buildings and never work to its fullest potential. There is also limited space on the roof because that is usually where the mechanical equipment is found. Without a decent size surface area it tends not to be practical to have photovoltaics.

Although the UMB New Administration building does not have very tall buildings to the South, East or West it does have a large rooftop mechanical system. A few options were considered such as building a structure above the mechanical equipment, laying the panels around the equipment, and actually attaching them to top of the equipment. All of these had some significant concerns. Building the structure involves redesign of some elements of the roof, adds cost for material and labor, and has constructability issues because it would need to be coordinated with things such as setting the AHUs, roof vents and roof construction.

For a smaller complementary system such as the one being explored there may have been enough space on either side of the mechanical system, which runs down the middle of the roof. This option is not optimal either because then the equipment becomes an obstruction and creates a shadow when the sun is not directly south of the building. A shadow on a small system reduces the output to the point that they mine as well not be there.

Finally, fastening the system directly to the mechanical equipment was explored. This was possible because the mechanical system is self enclosed so it was seen a structure that could withstand the impact of the photovoltaic system. There were two issues with this option. The AHU manufacturer did not approve of the extra weight or drilling holes into the self enclosed system. A special PV panel was researched that was not only thin, light and powerful but was installed using "Peel and Stick" technology. This would have been great because installation time is dramatically shortened and would require no drilling into the structure. However, these panels could not be tilted to an angle that would receive a lot of irradiance. Baltimore's latitude is too high for a flat array to be efficient. Flat arrays are good to low latitudes or areas that receive a lot of sun.

It was concluded that this building was not made for PV panels. The options that would work are not practical and the optimum options were not available. With the approach that the owner really wanted to implement PV, it was determined that the best solution was across the street. Across from the northwest corner of the building is another university owned building. It is a large 14 story building with the first 10 being a parking garage. The top 4 floors are the same administration people that will be moving into the UMB New Administration building. This building, like the Administration building, has rooftop mechanical but the roof surface area is easily large enough to house a PV system.

Below is a simple model showing both buildings and their rooftop air handling units (UMB New Administration Building is the smaller of the two).

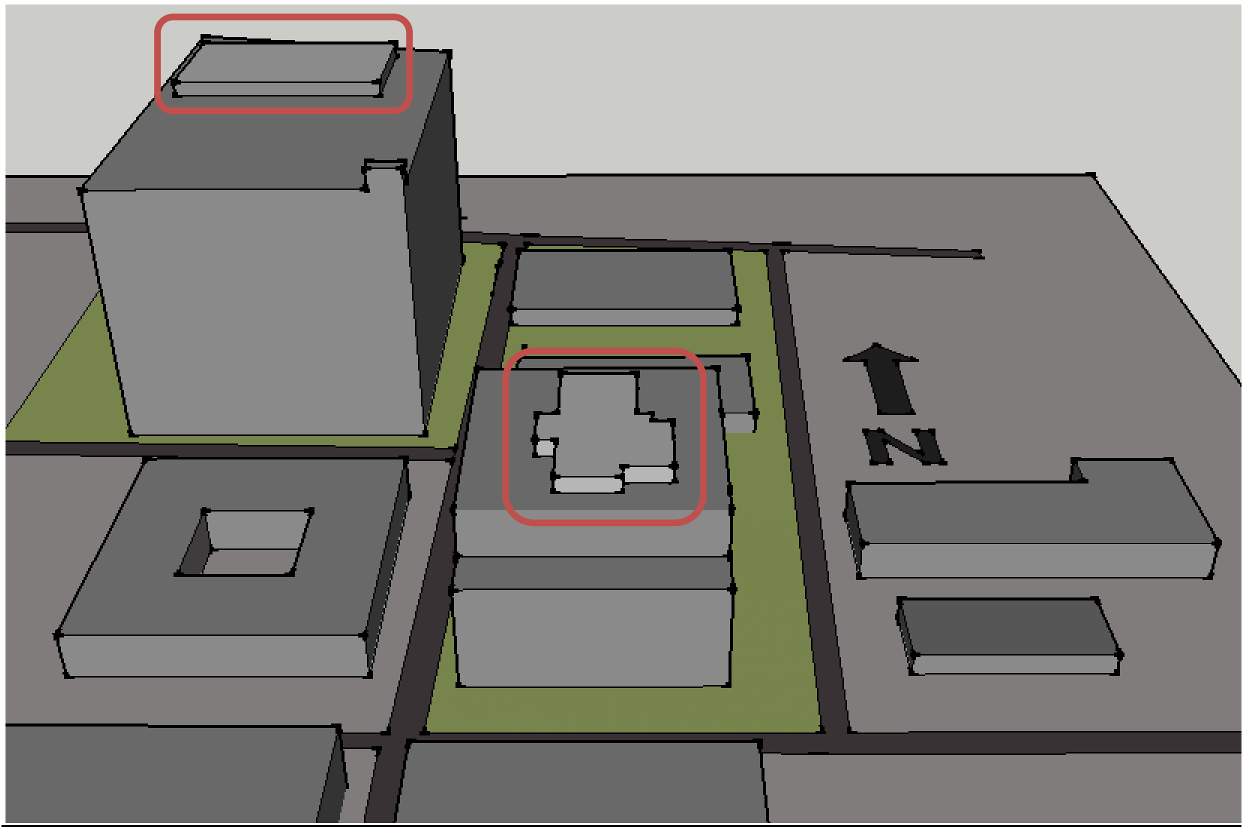


Figure 4.1 Model showing rooftop mechanical

From this investigation the location was chosen to be on top of a neighboring building that was owned by the university.

4.5.2 System Basics

The system was chosen to be complementary for a few reasons. The biggest were size and cost. A system that generated enough electricity for the UMB Admin Building would cost millions and would require too much space. So, a 10kW system (200 Watt Panels) was chosen. It is big enough to offset some energy expenses while the upfront costs are not so much that you can barely see the payback. It is also the university's first time implementing PV, so this size is good for them as a starting point to learn PV and figure out if they believe it is worth exploring on future projects.

The SX 3200B solar module was chosen and the manufacturer is BP Solar. The chosen inverter was the Fornius IG Plus 10kW inverter.

The module details are in the chart below.

BP SX3200B	
Wattage	200
Dimensions	66.14”x32.95”x1.97”
Cell Technology	Multicrystalline
Weight (EA)	37.84lbs

Table 4.1 PV module characteristics

A monocrystalline cell is slightly more efficient than a multicrystalline cell but multi was chosen for a few reasons. They are much cheaper to produce thus costing the owner less. Also multicrystalline cells can be packed very tightly in a module making them very competitive with monocrystalline cells.

Not only is BP proven and the system could be bought outside of Baltimore, but they offer a full service purchase. Panels, mounting system, installation, and commissioning are all included. They will train facility employees operations and maintenance or can be contracted to do that as well. This is a major convenience since there are many problems that can arise from piecing together all of the parts. Another positive of there program is that you know it will work and there are many cases of systems that do not work to their full potential because the facility managers are not correctly educated on the system.

4.5.3 System Configuration, Angle and Orientation – Electrical Breadth

The tilt angle and the array orientation are some of the most important factors when designing a photovoltaic system. Proper use of these will allow the array to harness as much sun as possible. The optimal tilt angle for a fixed mounted system, which is being proposed, is the latitude of the location minus its optimal tilt angle factor. The optimal tilt factor is developed by average climate conditions and a computer model. The factors are established for most areas and are available to the public. In this case Baltimore’s latitude is 39.18° and its optimal tilt factor is 8°. This gives the array an angle of 31.18°. From this the spacing of the modules is determined. The shadow casted by the module is calculated by the equation $d=\frac{h}{\tan(\alpha)}$,where d is the distance of the shadow, h is the height of the triangle made between the roof and the module and α is the solar altitude angle. The solar altitude angle is found from sun path charts. The shadow will be at its longest when the sun is at its lowest (9AM or 3PM on winter solstice). The solar altitude angle at these times in Baltimore is 14. If the optimal array angle of 31.18 were used then there would have to be 11.45’ between each module. The roof area of the proposed location is large enough so this spacing is acceptable.

As most know the best direction to orient the PV modules is towards the south. But a common mistake is when people orient the array to the magnetic south (using a compass). The array needs to should be oriented to true south. This is done by subtracting the declination (the angle between true north and magnetic north) from the compass reading. Baltimore's declination is -10° (10°W) and so when facing south the compass reads 180°. These numbers subtracted gives you 190°, so the array should be facing that 190° instead of 180°. Both buildings face magnetic south and so a 10° rotation will occur so the array faces true south.

One of the trickiest aspects of PV configuration is determining how many modules can be connected in series with each other. This has to do with the balance between the module and the inverter. An excel tool that was made based on a magazine article in SolarPro Magazine was used to determine the configuration that would yield the highest efficiency output of the inverter. The tool requires information about the module and inverter selected as well as temperature ranges of the location. After inputting the module and inverter technical data, the excel tool gives a range of possible configurations. It shows multiple combinations of modules in series and with how many strings. It also shows the efficiency of the particular configuration. The recommended efficiency is between 80% and 100%. If it is lower than 80% the system is not utilizing the full potential of the inverter. Sometimes larger inverters are purchased with the intention of increasing the array size later on down the road. After interpreting the program's scenarios it was decided that the best configuration is 60 modules on 5 different series strings. This configuration yields an efficiency of 97%. This means that 97% of the DC power collected by the panels will become AC power (which is used in the building). Below is a portion of the chart that is in the excel tool as well as another model that shows the angle, orientation and location of the array. The configurations that are above 80% efficiency automatically become highlighted. For complete charts of the program see Appendix E.

Number of modules in series	5 Strings			6 Strings		
	#	Pac out (W)	% of max	#	Pac out (W)	% of max
1	5	811	8	6	973	10
2	10	1622	16	12	1947	19
3	15	2433	24	18	2920	29
4	20	3244	32	24	3893	39
5	25	4055	41	30	4867	49
6	30	4867	49	36	5840	58
7	35	5678	57	42	6813	68
8	40	6489	65	48	7786	78
9	45	7300	73	54	8760	**88**
10	50	8111	**81**	60	9733	**97**
11	55	8922	**89**	66	10706	**107**
12	60	9733	**97**	72	11680	117
13	65	10544	**105**	78	12653	127
14	70	11355	114	84	13626	136
15	75	12166	122	90	14600	146
16	80	12977	130	96	15573	156
17	85	13788	138	102	16546	165
18	90	14600	146	108	17519	175

Figure4.2 Excel series connection optimizer

Below are images showing the proposed array and configuration.

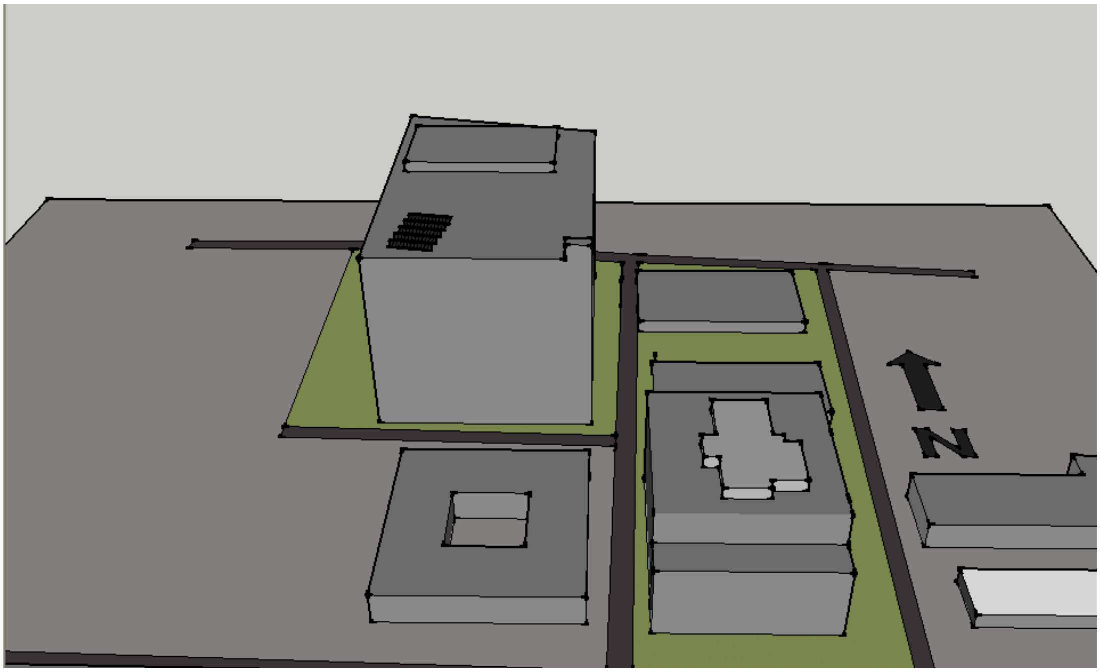


Figure 4.3 Proposed PV location and configuration

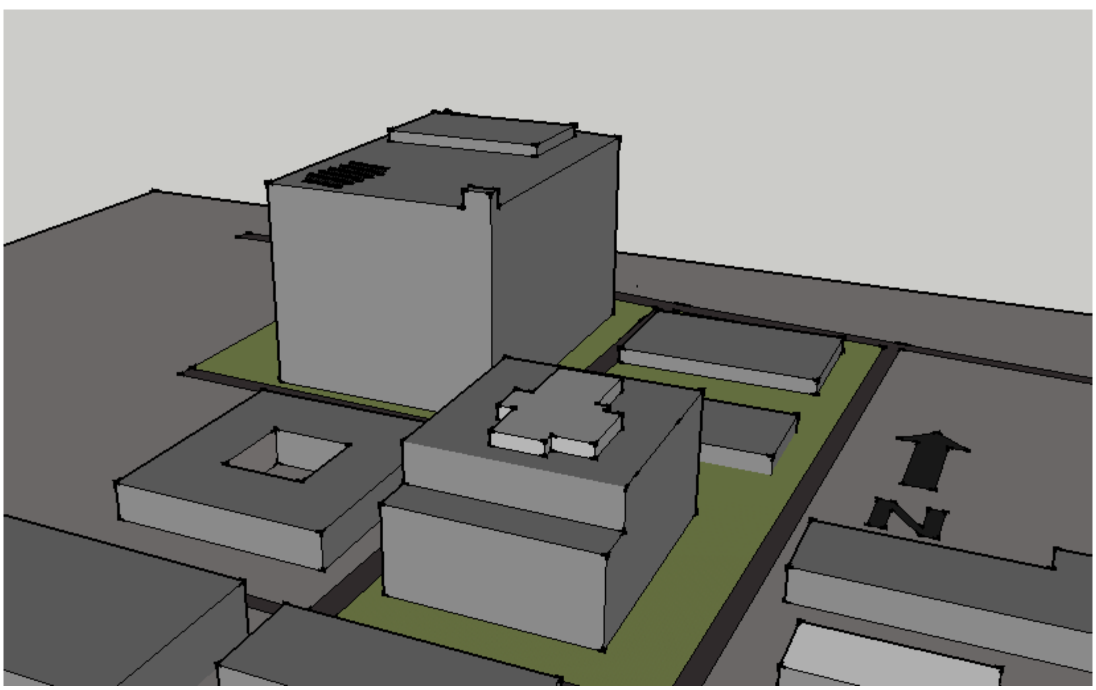


Figure 4.4 Proposed PV location and configuration

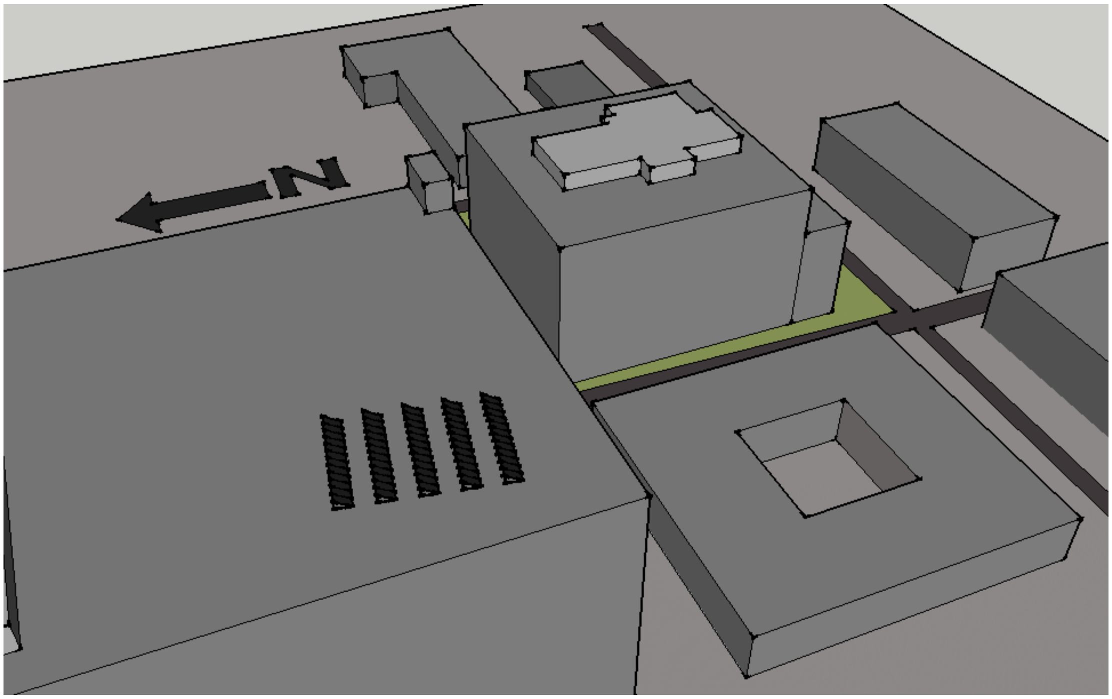


Figure 4.5 Proposed PV location and configuration

4.6 Cost Impact

Calculating the ramifications of cost can be very difficult because everyday the array receives different amounts of sunlight and so the system will produce different amounts of electricity each day. However there are tools out there that assist in the estimation of energy savings for a system.

Two methods were used to estimate the cost and annual savings involved with this PV system. The first was from the BP Solar website. There is a “quick estimator” within this site that takes into account things like building location, monthly energy bill, state and federal tax rebates, and price escalation to better estimate the costs and savings. The estimator provides multiple charts and graphs to show rough annual savings, 1st year cost, daily PV production, etc. This is a good source because it is the product manufacturer’s website so it knows the modules well. A reason for concern is the same. It is not great practice to solely rely on the manufacturer for correct pricing information.

The second method was using PVWatts which is a website that asks for inputs about the system and then estimates the annual energy savings. A good thing about this site is that it is not affiliated with a manufacturer so they have no reason to skew numbers and it also gives the consumer another estimation to make comparisons.

Finding a concrete $/W cost for PVs is difficult. Most have been in between $6 and $8 so $7 was used to estimate total cost. Using $7 the system will cost roughly $70,000 which includes installation, inverter (10%-20%), mounting system, etc.

Both the BP Solar estimate and PVWatts has the system saving about $1900 on the first year's energy bill. Charts showing this can be seen in Appendix F. Since the estimates are so close and BP takes into account more factors, that estimation was used to calculate payback period.

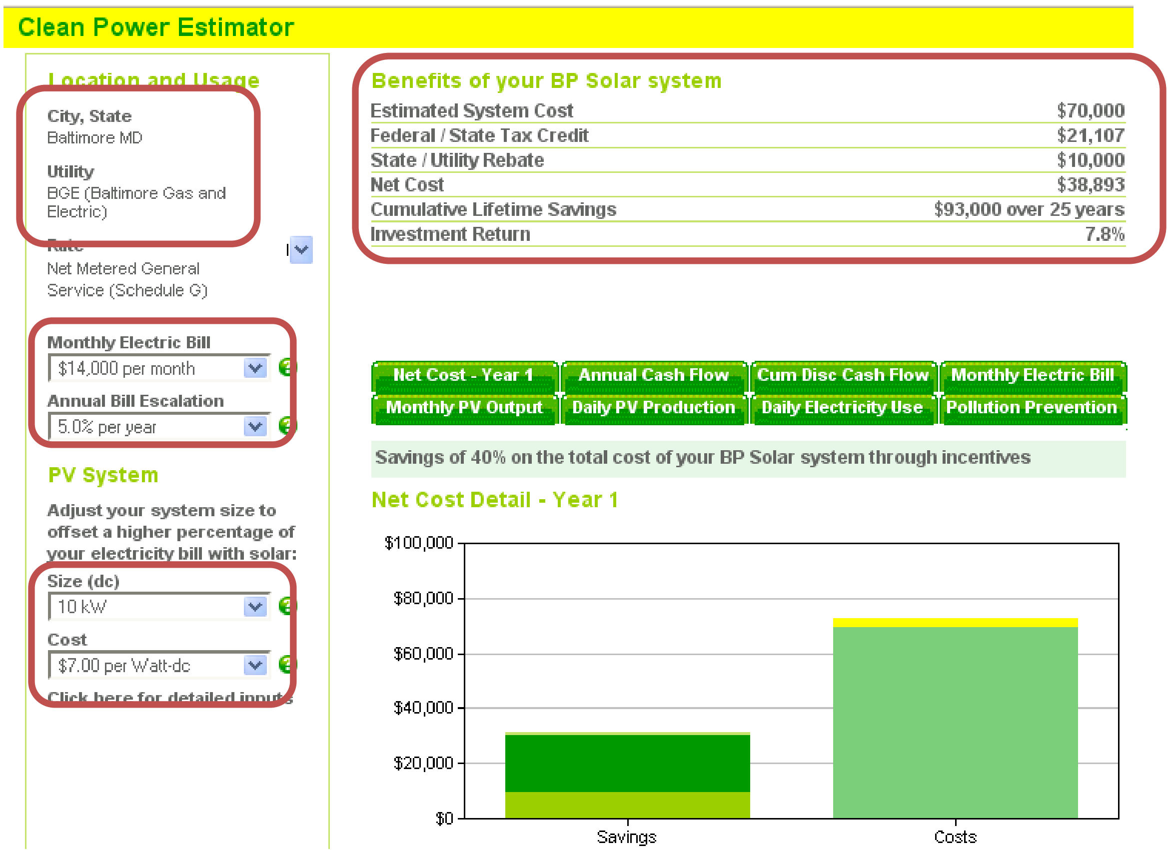


Figure 4.6 Clean power estimator from BP website

The screen shot above is from BP's "Clean Power Estimator". $14,000 was used as the monthly electric bill based on the electric consumption estimate in the previous analysis. A system of this size would save 40% through state and federal tax incentives yielding a total upfront cost of $38, 893.

BP also estimates annual cash flow for over 20 years taking into account electric savings, electric bill tax savings, and depreciation tax savings. There also is a 5% tax escalation added each year. These numbers were used to calculate the payback period of this system.

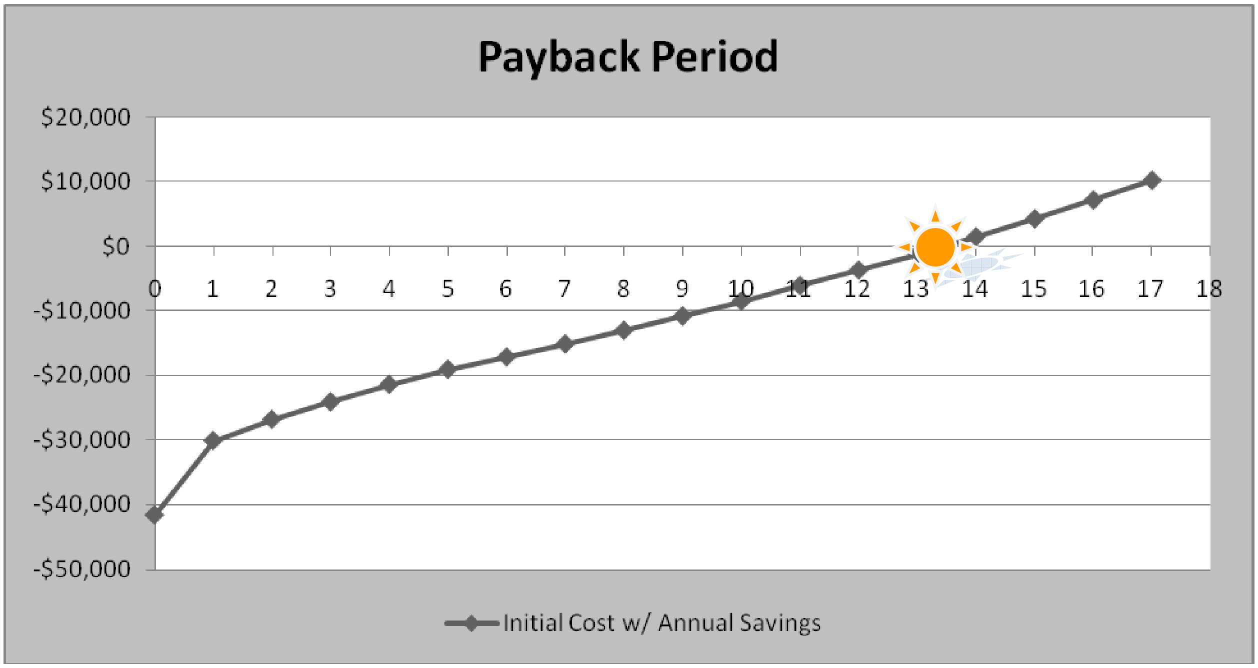


Figure 4.7 Estimated payback period for proposed system

As shown in the graph above it takes a little over 13 years for the system to pay for itself and begin saving.

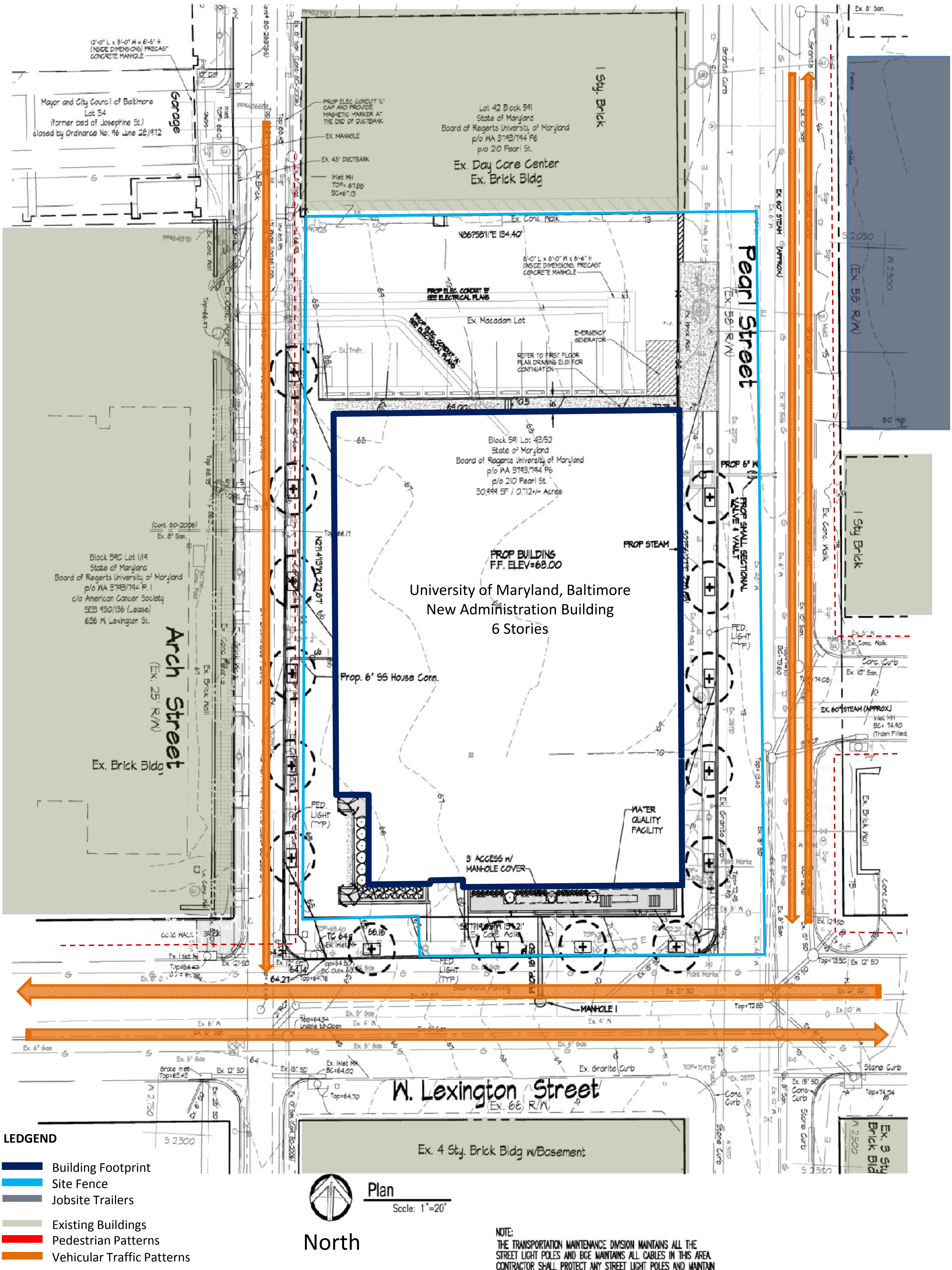
4.7 Schedule Impact

The project schedule is not affected since the construction is done on a different site. After speaking with BP Solar it was concluded that a crew of two can install about a panel an hour. Sixty panels at 8 hours a day gives an estimated time of 7.5 work days. The cost of this installation was already factored into BP's cost estimate.

4.8 Conclusion and Recommendation

After reviewing the analysis and considering the owner's view, it is recommended that this photovoltaic system be installed. It has many positives and will give the university a chance to explore energy conservation through renewable energy. The cost after incentives is not very significant when compared to the overall project cost (plus there is money left over from the analysis above) and the payback period is not too long for the owner to wait to collect the benefits. This installation will prove useful not only financially but will provide education on PV and its possible implementation on future projects.

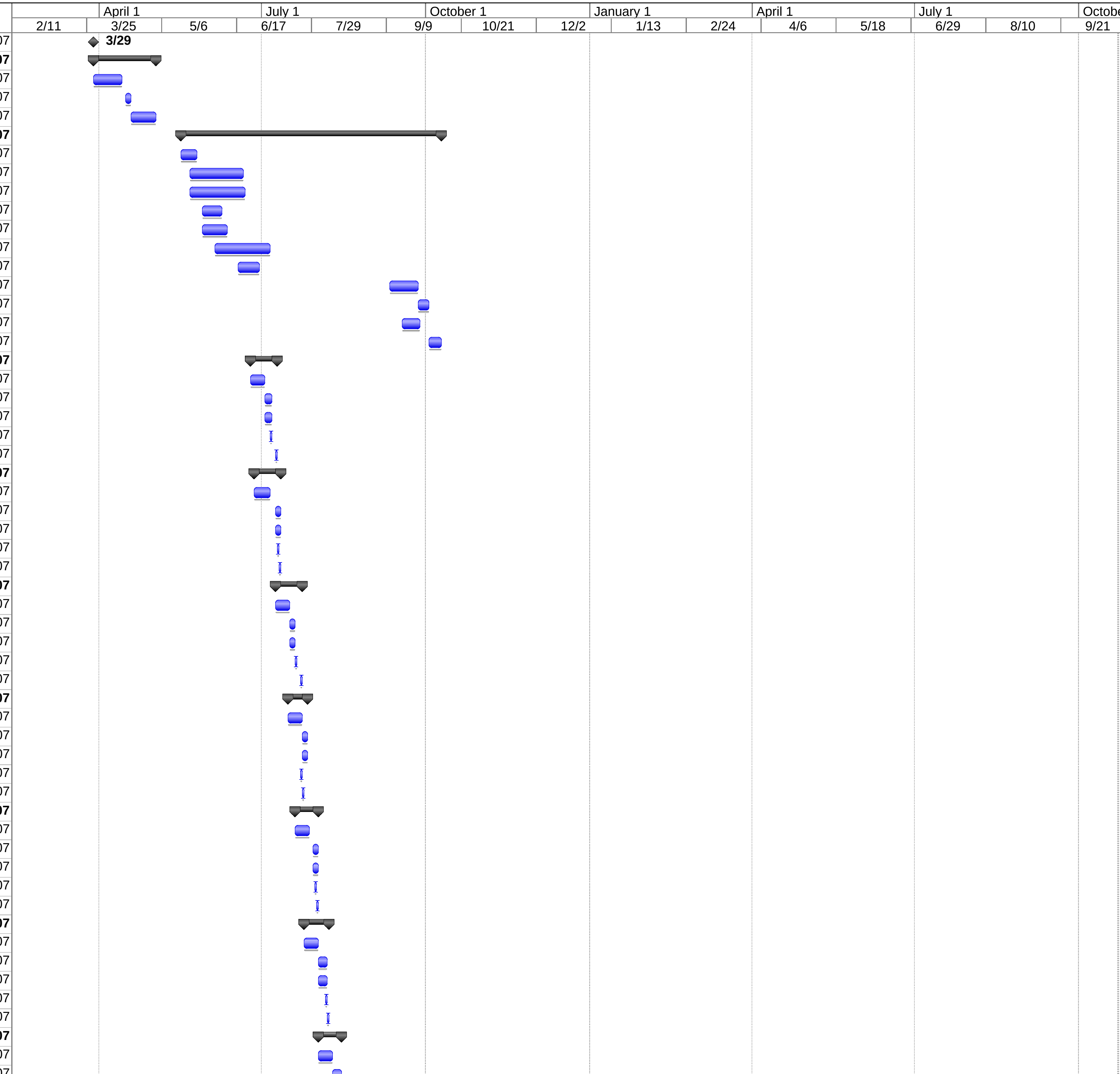
Appendix A - Site Plans



University of Maryland, Baltimore
New Administration Building
6 Stories
PROP BUILDING
F.F. ELEV=68.00
Block 591 Lot 43/52
State of Maryland
Board of Regents University of Maryland
p/o WA 3793/194 P6
p/o 210 Pearl St.
30,999 SF / 0.712+/- Acres
Lot 42 Block 591
State of Maryland
Board of Regents University of Maryland
p/o WA 3793/194 F6
p/o 210 Pearl St.
Ex. Day Care Center
Ex. Brick Bldg
1 Sty. Brick
Ex. Macadam Lot
EMERGENCY GENERATOR
REFER TO FIRST FLOOR PLAN DRAWING E1.01 FOR CONTINUATION
PROP STEAM
PROP SMALL SECTIONAL VALVE & VAULT
Prop. 6" SS House Conn.
WATER QUALITY FACILITY
3' ACCESS w/ MANHOLE COVER
PED. LIGHT (TYP.)
Pearl Street
(Ex. 58' R/W)
Arch Street
(Ex. 25' R/W)
Block 590 Lot 1/19
State of Maryland
Board of Regents University of Maryland
p/o WA 3793/194 P. 1
c/o American Cancer Society
SEB 930/136 (Lease)
636 W. Lexington St.
Ex. Brick Bldg
Mayor and City Council of Baltimore
Lot 34
(former bed of Josephine St.)
closed by Ordinance No. 96 June 28, 1972
Garage
W. Lexington Street
(Ex. 66' R/W)
Ex. 4 Sty. Brick Bldg w/Basement
Ex. 3 Sty Brick Bldg
1 Sty Brick
MANHOLE 1
LEDGEND
Building Footprint
Site Fence
Jobsite Trailers
Existing Buildings
Pedestrian Patterns
Vehicular Traffic Patterns
North
Plan
Scale: 1"=20'
NOTE:
THE TRANSPORTATION MAINTENANCE DIVISION MAINTAINS ALL THE STREET LIGHT POLES AND BGE MAINTAINS ALL CABLES IN THIS AREA. CONTRACTOR SHALL PROTECT ANY STREET LIGHT POLES AND MAINTAIN

Appendix B - Project Schedule

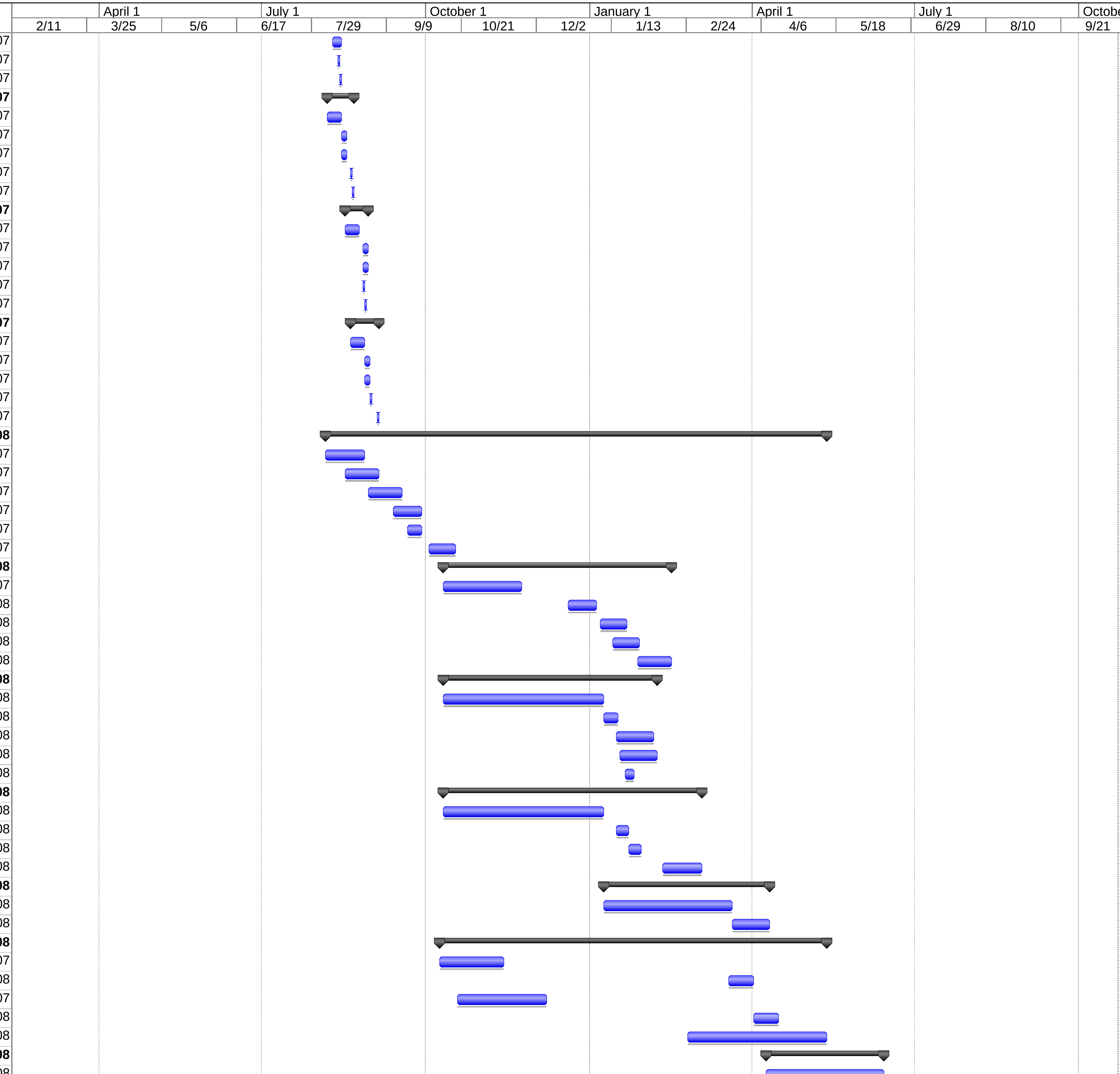
ID	Task Name	Duration	Start	Finish
1	Start of Construction	0 days	Thu 3/29/07	Thu 3/29/07
2	**Excavation**	**25 days**	**Thu 3/29/07**	**Wed 5/2/07**
3	INITIAL SED/ER SITE DEMO	12 days	Thu 3/29/07	Fri 4/13/07
4	MOBILIZE FOR SHEETING & SHORING	3 days	Mon 4/16/07	Wed 4/18/07
5	MASS EXCV/SHEETING & SHORING	10 days	Thu 4/19/07	Wed 5/2/07
6	**Substructure**	**100 days**	**Thu 5/17/07**	**Tue 10/9/07**
7	CL 1-5/A-C (Pilecaps & Grade Beams)	7 days	Thu 5/17/07	Fri 5/25/07
8	FRP Sandfilter	21 days	Tue 5/22/07	Wed 6/20/07
9	FRP Elev/Stair 1 Pilecap Slab	22 days	Tue 5/22/07	Thu 6/21/07
10	CL 1-5/C-F (Perimeter/Interior Pilecaps & Grade Beams)	9 days	Tue 5/29/07	Fri 6/8/07
11	CL 1-5/A-F (FRP Cols)	10 days	Tue 5/29/07	Mon 6/11/07
12	FRP Perimeter Walls	22 days	Tue 6/5/07	Thu 7/5/07
13	North/South Backfill	10 days	Mon 6/18/07	Fri 6/29/07
14	North - Underground plumb/elec R/I	12 days	Tue 9/11/07	Wed 9/26/07
15	North - Prep/Pour SOG	4 days	Thu 9/27/07	Tue 10/2/07
16	South - Underground plumb/elec R/I	8 days	Tue 9/18/07	Thu 9/27/07
17	South - Prep/Pour SOG	4 days	Wed 10/3/07	Tue 10/9/07
18	**LV2 North**	**10 days**	**Mon 6/25/07**	**Mon 7/9/07**
19	FRP Slab	6 days	Mon 6/25/07	Mon 7/2/07
20	FRP Columns	3 days	Tue 7/3/07	Fri 7/6/07
21	FRP Shear Walls	3 days	Tue 7/3/07	Fri 7/6/07
22	Post Tension Slab	1 day	Fri 7/6/07	Fri 7/6/07
23	Strip Forms/Install Reshore	1 day	Mon 7/9/07	Mon 7/9/07
24	**LV2 South**	**10 days**	**Wed 6/27/07**	**Wed 7/11/07**
25	FRP Slab	6 days	Wed 6/27/07	Thu 7/5/07
26	FRP Columns	3 days	Mon 7/9/07	Wed 7/11/07
27	FRP Shear Walls	3 days	Mon 7/9/07	Wed 7/11/07
28	Post Tension Slab	1 day	Tue 7/10/07	Tue 7/10/07
29	Strip Forms/Install Reshore	1 day	Wed 7/11/07	Wed 7/11/07
30	**LV3 North**	**11 days**	**Mon 7/9/07**	**Mon 7/23/07**
31	FRP Slab	6 days	Mon 7/9/07	Mon 7/16/07
32	FRP Columns	3 days	Tue 7/17/07	Thu 7/19/07
33	FRP Shear Walls	3 days	Tue 7/17/07	Thu 7/19/07
34	Post Tension Slab	1 day	Fri 7/20/07	Fri 7/20/07
35	Strip Forms/Install Reshore	1 day	Mon 7/23/07	Mon 7/23/07
36	**LV3 South**	**9 days**	**Mon 7/16/07**	**Thu 7/26/07**
37	FRP Slab	6 days	Mon 7/16/07	Mon 7/23/07
38	FRP Columns	3 days	Tue 7/24/07	Thu 7/26/07
39	FRP Shear Walls	3 days	Tue 7/24/07	Thu 7/26/07
40	Post Tension Slab	1 day	Mon 7/23/07	Mon 7/23/07
41	Strip Forms/Install Reshore	1 day	Tue 7/24/07	Tue 7/24/07
42	**LV4 North**	**9 days**	**Fri 7/20/07**	**Wed 8/1/07**
43	FRP Slab	6 days	Fri 7/20/07	Fri 7/27/07
44	FRP Columns	3 days	Mon 7/30/07	Wed 8/1/07
45	FRP Shear Walls	3 days	Mon 7/30/07	Wed 8/1/07
46	Post Tension Slab	1 day	Tue 7/31/07	Tue 7/31/07
47	Strip Forms/Install Reshore	1 day	Wed 8/1/07	Wed 8/1/07
48	**LV4 South**	**10 days**	**Wed 7/25/07**	**Tue 8/7/07**
49	FRP Slab	6 days	Wed 7/25/07	Wed 8/1/07
50	FRP Columns	3 days	Thu 8/2/07	Mon 8/6/07
51	FRP Shear Walls	3 days	Thu 8/2/07	Mon 8/6/07
52	Post Tension Slab	1 day	Mon 8/6/07	Mon 8/6/07
53	Strip Forms/Install Reshore	1 day	Tue 8/7/07	Tue 8/7/07
54	**LV5 North**	**9 days**	**Thu 8/2/07**	**Tue 8/14/07**
55	FRP Slab	6 days	Thu 8/2/07	Thu 8/9/07
56	FRP Columns	3 days	Fri 8/10/07	Tue 8/14/07



Project: Tech 2 Sched.mpp
Date: Thu 10/23/08

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

ID	Task Name	Duration	Start	Finish
57	FRP Shear Walls	3 days	Fri 8/10/07	Tue 8/14/07
58	Post Tension Slab	1 day	Mon 8/13/07	Mon 8/13/07
59	Strip Forms/Install Reshore	1 day	Tue 8/14/07	Tue 8/14/07
60	**LV5 South**	**11 days**	**Tue 8/7/07**	**Tue 8/21/07**
61	FRP Slab	6 days	Tue 8/7/07	Tue 8/14/07
62	FRP Columns	3 days	Wed 8/15/07	Fri 8/17/07
63	FRP Shear Walls	3 days	Wed 8/15/07	Fri 8/17/07
64	Post Tension Slab	1 day	Mon 8/20/07	Mon 8/20/07
65	Strip Forms/Install Reshore	1 day	Tue 8/21/07	Tue 8/21/07
66	**LV6 North**	**9 days**	**Fri 8/17/07**	**Wed 8/29/07**
67	FRP Slab	6 days	Fri 8/17/07	Fri 8/24/07
68	FRP Columns	3 days	Mon 8/27/07	Wed 8/29/07
69	FRP Shear Walls	3 days	Mon 8/27/07	Wed 8/29/07
70	Post Tension Slab	1 day	Mon 8/27/07	Mon 8/27/07
71	Strip Forms/Install Reshore	1 day	Tue 8/28/07	Tue 8/28/07
72	**LV6 South**	**11 days**	**Mon 8/20/07**	**Tue 9/4/07**
73	FRP Slab	6 days	Mon 8/20/07	Mon 8/27/07
74	FRP Columns	3 days	Tue 8/28/07	Thu 8/30/07
75	FRP Shear Walls	3 days	Tue 8/28/07	Thu 8/30/07
76	Post Tension Slab	1 day	Fri 8/31/07	Fri 8/31/07
77	Strip Forms/Install Reshore	1 day	Tue 9/4/07	Tue 9/4/07
78	**Enclosure**	**193 days**	**Mon 8/6/07**	**Mon 5/12/08**
79	LV1 North/South (Perimeter Studs & Sheathing)	16 days	Mon 8/6/07	Mon 8/27/07
80	LV2 North/South (Perimeter Studs & Sheathing)	12 days	Fri 8/17/07	Tue 9/4/07
81	LV3 North/South (Perimeter Studs & Sheathing)	12 days	Thu 8/30/07	Mon 9/17/07
82	LV4 North/South (Perimeter Studs & Sheathing)	12 days	Thu 9/13/07	Fri 9/28/07
83	LV5 North/South (Perimeter Studs & Sheathing)	6 days	Fri 9/21/07	Fri 9/28/07
84	LV6 North/South & Parapet (Perimeter Studs & Sheathing	10 days	Wed 10/3/07	Wed 10/17/07
85	**South Elevation Exterior (w/ curtain wall)**	**87 days**	**Thu 10/11/07**	**Fri 2/15/08**
86	Exterior Brick	30 days	Thu 10/11/07	Fri 11/23/07
87	Metal Panels	10 days	Thu 12/20/07	Fri 1/4/08
88	Windows	10 days	Mon 1/7/08	Mon 1/21/08
89	Storefronts	10 days	Mon 1/14/08	Mon 1/28/08
90	Curtain Wall	15 days	Mon 1/28/08	Fri 2/15/08
91	**West Elevation Exterior (w/ curtain wall)**	**81 days**	**Thu 10/11/07**	**Thu 2/7/08**
92	Exterior Brick	60 days	Thu 10/11/07	Tue 1/8/08
93	Metal Panels	5 days	Wed 1/9/08	Wed 1/16/08
94	Storefronts	15 days	Wed 1/16/08	Tue 2/5/08
95	Curtain Wall	15 days	Fri 1/18/08	Thu 2/7/08
96	Windows	5 days	Mon 1/21/08	Fri 1/25/08
97	**East Elevation Exterior**	**97 days**	**Thu 10/11/07**	**Mon 3/3/08**
98	Exterior Brick	60 days	Thu 10/11/07	Tue 1/8/08
99	Metal Panels	5 days	Wed 1/16/08	Tue 1/22/08
100	Storefronts	5 days	Wed 1/23/08	Tue 1/29/08
101	Windows	15 days	Mon 2/11/08	Mon 3/3/08
102	**North Elevation Exterior**	**65 days**	**Wed 1/9/08**	**Thu 4/10/08**
103	Exterior Brick	50 days	Wed 1/9/08	Thu 3/20/08
104	Windows	15 days	Fri 3/21/08	Thu 4/10/08
105	**Roof**	**149 days**	**Tue 10/9/07**	**Mon 5/12/08**
106	High Roof (Curbs/Drains/Blocking/Roofing)	25 days	Tue 10/9/07	Tue 11/13/07
107	High Roof (Trimout)	10 days	Wed 3/19/08	Tue 4/1/08
108	Low Roof (Curbs/Drains/Blocking/Roofing)	34 days	Fri 10/19/07	Fri 12/7/07
109	Low Roof (Trimout)	10 days	Wed 4/2/08	Tue 4/15/08
110	Rooftop Mechanical	56 days	Mon 2/25/08	Mon 5/12/08
111	**Sitework**	**47 days**	**Wed 4/9/08**	**Fri 6/13/08**
112	Sitework	47 days	Wed 4/9/08	Fri 6/13/08



Project: Tech 2 Sched.mpp
Date: Thu 10/23/08

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

ID	Task Name	Duration	Start	Finish
113	**Electrical/ Mechanical Rooms**	**95 days**	**Tue 10/9/07**	**Tue 2/26/08**
114	Electrical Room	84 days	Tue 10/9/07	Fri 2/8/08
115	Mechanical Room	95 days	Tue 10/9/07	Tue 2/26/08
116	**Elevators**	**67 days**	**Mon 1/21/08**	**Wed 4/23/08**
117	Elevator No. 1	57 days	Mon 2/4/08	Wed 4/23/08
118	Elevator No. 2	52 days	Mon 1/21/08	Wed 4/2/08
119	**LV2 Rough-In and Finishes**	**208 days?**	**Fri 9/7/07**	**Mon 7/7/08**
120	Install Electrical and Fire Alarm System	111 days	Fri 9/7/07	Tue 2/19/08
121	Frame/Hang/Tape Dryw. (Corridor)	15 days?	Mon 9/17/07	Sun 10/7/07
122	Install/Insulate HVAC Duct/Pipe	136 days	Tue 10/9/07	Wed 4/23/08
123	Install Sprinkler Mains, Branches, Drops	139 days?	Tue 11/27/07	Fri 6/13/08
124	Hang/Tape/Finish Dryw. Walls (Inner and Perimeter Offices)	17 days	Thu 12/13/07	Tue 1/8/08
125	Install Domestic and Sanitary Mains/Branches/Vents/Fixtures	50 days	Thu 12/13/07	Tue 2/26/08
126	Install Doors and Hardware	10 days	Tue 5/13/08	Tue 5/27/08
127	Final Clean/Punch Out	15 days?	Mon 6/16/08	Mon 7/7/08
128	**LV3 Rough-In and Finishes**	**211 days?**	**Tue 9/11/07**	**Mon 7/14/08**
129	Install/Insulate HVAC Duct/Pipe	136 days	Tue 9/11/07	Thu 3/27/08
130	Install Electrical and Fire Alarm System	111 days	Wed 9/12/07	Fri 2/22/08
131	Frame/Hang/Tape Dryw. (Corridor)	15 days?	Wed 9/19/07	Wed 10/10/07
132	Install Domestic and Sanitary Mains/Branches/Vents/Fixtures	50 days	Thu 12/20/07	Tue 3/4/08
133	Install Sprinkler Mains, Branches, Drops	124 days?	Wed 12/26/07	Fri 6/20/08
134	Hang/Tape/Finish Dryw. Walls (Inner and Perimeter Offices)	17 days	Thu 1/31/08	Mon 2/25/08
135	Install Doors and Hardware	10 days	Tue 5/20/08	Tue 6/3/08
136	Final Clean/Punch Out	15 days?	Mon 6/23/08	Mon 7/14/08
137	**LV4 Rough-In and Finishes**	**211 days?**	**Tue 9/18/07**	**Mon 7/21/08**
138	Install/Insulate HVAC Duct/Pipe	136 days	Tue 9/18/07	Thu 4/3/08
139	Install Electrical and Fire Alarm System	111 days	Tue 9/18/07	Thu 2/28/08
140	Frame/Hang/Tape Dryw. (Corridor)	15 days?	Fri 9/21/07	Fri 10/12/07
141	Install Domestic and Sanitary Mains/Branches/Vents/Fixtures	50 days	Fri 12/28/07	Tue 3/11/08
142	Install Sprinkler Mains, Branches, Drops	116 days?	Wed 1/16/08	Fri 6/27/08
143	Hang/Tape/Finish Dryw. Walls (Inner and Perimeter Offices)	17 days	Mon 2/11/08	Wed 3/5/08
144	Install Doors and Hardware	10 days	Wed 5/28/08	Tue 6/10/08
145	Final Clean/Punch Out	15 days?	Mon 6/30/08	Mon 7/21/08
146	**LV5 Rough-In and Finishes**	**221 days?**	**Fri 9/21/07**	**Wed 8/6/08**
147	Install/Insulate HVAC Duct/Pipe	136 days	Mon 9/24/07	Wed 4/9/08
148	Install Electrical and Fire Alarm System	111 days	Fri 9/21/07	Tue 3/4/08
149	Frame/Hang/Tape Dryw. (Corridor)	15 days?	Tue 9/25/07	Tue 10/16/07
150	Install Domestic and Sanitary Mains/Branches/Vents/Fixtures	50 days	Mon 1/7/08	Tue 3/18/08
151	Install Sprinkler Mains, Branches, Drops	111 days?	Wed 1/30/08	Mon 7/7/08
152	Hang/Tape/Finish Dryw. Walls (Inner and Perimeter Offices)	17 days	Wed 4/30/08	Thu 5/22/08
153	Install Doors and Hardware	10 days	Wed 6/4/08	Tue 6/17/08
154	Final Clean/Punch Out	16 days?	Thu 7/17/08	Wed 8/6/08
155	**LV6 Rough-In and Finishes**	**152 days?**	**Tue 10/9/07**	**Thu 5/15/08**
156	Install/Insulate HVAC Duct/Pipe	109 days	Tue 10/9/07	Mon 3/17/08
157	Install Electrical and Fire Alarm System	74 days	Tue 10/9/07	Fri 1/25/08
158	Install Domestic and Sanitary Mains/Branches/Vents/Fixtures	7 days	Mon 1/14/08	Wed 1/23/08
159	Final clean/Punch Out	15 days?	Fri 4/25/08	Thu 5/15/08
160	**LV1 Rough-In and Finishes**	**213 days?**	**Thu 10/11/07**	**Wed 8/13/08**
161	Install/Insulate HVAC Duct/Pipe	136 days	Fri 10/12/07	Mon 4/28/08
162	Install Electrical and Fire Alarm System	111 days	Fri 10/12/07	Mon 3/24/08
163	Frame/Hang/Tape Dryw. (Corridor)	15 days?	Thu 10/11/07	Wed 10/31/07
164	Install Domestic and Sanitary Mains/Branches/Vents/Fixtures	50 days	Wed 1/16/08	Wed 3/26/08
165	Install Sprinkler Mains, Branches, Drops	102 days?	Wed 2/20/08	Mon 7/14/08
166	Hang/Tape/Finish Dryw. Walls (Inner and Perimeter Offices)	17 days	Wed 5/7/08	Fri 5/30/08
167	Install Doors and Hardware	10 days	Wed 5/7/08	Tue 5/20/08
168	Final Clean/Punch Out	16 days	Thu 7/24/08	Wed 8/13/08

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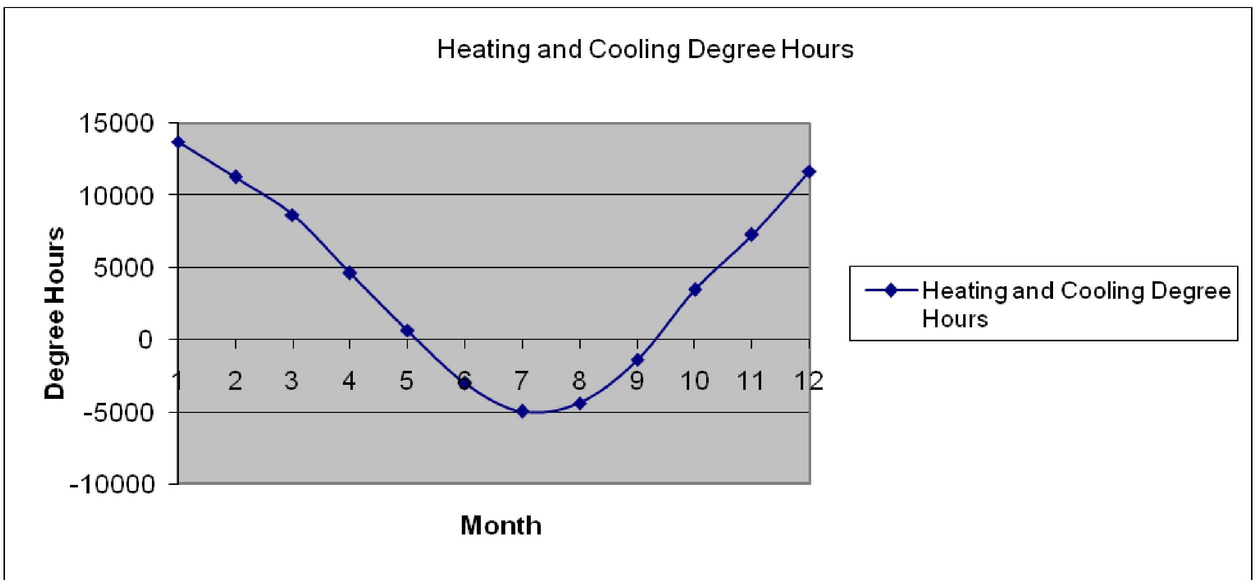
Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Appendix C - Degree Days for Baltimore, MD

	January	February	March	April	May	June	July	August	September	October	November	December
Heating and Cooling Degree Days	572	470	360	193	27	-126	-207	-183	-58	144	303	487



Appendix D - eQuest Energy Break Downs

	Baseline Building	Building A
Description	This is the building that was constructed	This is the Baseline Building with additional rigid insulation and the R-21 batt
Annual Electric Consumption (kWh)	1,242,900.0	1,242,900.0
Space Heating (kWh)	10,200.0	10,000.0
Space Cooling (kWh)	276,000.0	276,400.0
Annual Gas Consumption (BTU)	793,690,000.0	761,620,000.0
Space Heating (BTU)	603,310,000.0	571,240,000.0

	Baseline Building	Building B	Building C
Description	This is the building that was constructed	This is the Baseline Building w/ Viracon's VUE-50 series CLEAR	This is the Baseline Building w/ Viracon's VUE-50 series GREY
Annual Electric Consumption (kWh)	1,242,900.0	1,210,200.0	1,178,300.0
Space Heating (kWh)	10,200.0	10,000.0	10,300.0
Space Cooling (kWh)	276,000.0	258,600.0	239,500.0
Annual Gas Consumption (BTU)	793,690,000.0	690,800,000.0	691,800,000.0
Space Heating (BTU)	603,310,000.0	500,410,000.0	501,380,000.0

	Baseline Building	Building D
Description	This is the building that was constructed	This is the Baseline Building without finned tube heaters
Annual Electric Consumption (kWh)	1,242,900.0	1,232,400.0
Space Heating (kWh)	10,200.0	35,100.0
Space Cooling (kWh)	276,000.0	257,200.0
Annual Gas Consumption (BTU)	793,690,000.0	432,640,000.0
Space Heating (BTU)	603,310,000.0	242,140,000.0

	Baseline Building	Building E	Building F
Description	This is the building that was constructed	This is the combination of Building A, B and D	This is the combination of Building A, C and D
Annual Electric Consumption (kWh)	1,242,900.0	1,198,000.0	1,166,000.0
Space Heating (kWh)	10,200.0	30,200.0	33,400.0
Space Cooling (kWh)	276,000.0	243,100.0	221,100.0
Annual Gas Consumption (BTU)	793,690,000.0	402,630,000.0	443,380,000.0
Space Heating (BTU)	603,310,000.0	212,160,000.0	252,850,000.0

Appendix E - PV Calculation Excel Sheets

Panel Characteristics at STC				
Rated power at STC (Pmp)	200	W	Temp Coefficient of Pmp (/°C)	**-0.0050**
Open circuit voltage (Voc)	30.8	V	Temp Coefficient of Voc (/°C)	-0.0047
Maximum power voltage (Vmp)	24.5	V	Temp Coefficient of Vmp (/°C)	-0.0034
Short-circuit current (Isc)	8.7	A	Temp Coefficient of Isc (/°C)	**0.00065**
Maximum power current (Imp)	8.1	A	Temp Coefficient of Imp (/°C)	-0.0002
Rated power at PTC (Pptc)	177.5	W	UL series fuse rating (amps)	15

Inverter	
Power (W)	10000
Number	1
Input V_min	230
Input V_max	600
MPPT min	230
MPPT max	500
Input I_max	46.7
Efficiency	0.962
Derate Factor	0.95

NEC Table 690.7 Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules		
Correction Factors for Ambient Temperatures Below 25 deg. C (77 deg. F) (Multiply the rated circuit voltage by the appropriate correction factor shown below)		
Ambient Temperature (°C)	**Factor**	**Ambient Temperature (°F)**
24 to 20	1.02	76 to 68
19 to 15	1.04	67 to 59
14 to 10	1.06	58 to 50
9 to 5	1.08	49 to 41
4 to 0	1.1	40 to 32
-1 to -5	1.12	31 to 23
-6 to -10	1.14	22 to 14
-11 to -15	1.16	13 to 5
-16 to -20	1.18	4 to -4
-21 to -25	1.2	-5 to -13
-26 to -30	1.21	-14 to -22
-31 to -35	1.23	-23 to -31
-36 to -40	1.25	-32 to -40

Maximum Modules in Series (Manual)	
Voc max =	Voc + (temp differential * temp coefficient of Voc)
=	**38.1828**
Nmax ≤	Inverter input Vdc_max ÷ Voc_max
≤	15.7138981
=	**15**

Minimum Modules in Series

Vmp_min =	Vmp + (temp differential * temp coefficient of Vmp)
=	Vmp + ((Trise + Tmax - Tstc)*(temp coef. of Vmp * Vmp)
Vmp_min =	**19.4334**
Nmin ≥	Inverter input Vdc_min ÷ Vmp_min
≥	11.8352939
Nmin =	**12**

Max Strings in Parallel

N ≤	Inverter Input I_max ÷ Imp
≤	5.7654321
N =	**5**

Maximum Array Capacity

Inverter power ≤	N * PTC * CEC weighted efficiency	
N ≤	Power ÷ PTC ÷ CEC weighted efficiency	
≤	58.5634388	
N ≤	**58**	**modules**

With Additional Derate Factor

Inverter power ≤	N * PTC * CEC weighted efficiency * Derate factor	
N ≤	Power ÷ PTC ÷ CEC weighted efficiency ÷ Derate factor	
≤	61.6457251	
N ≤	**61**	**modules**

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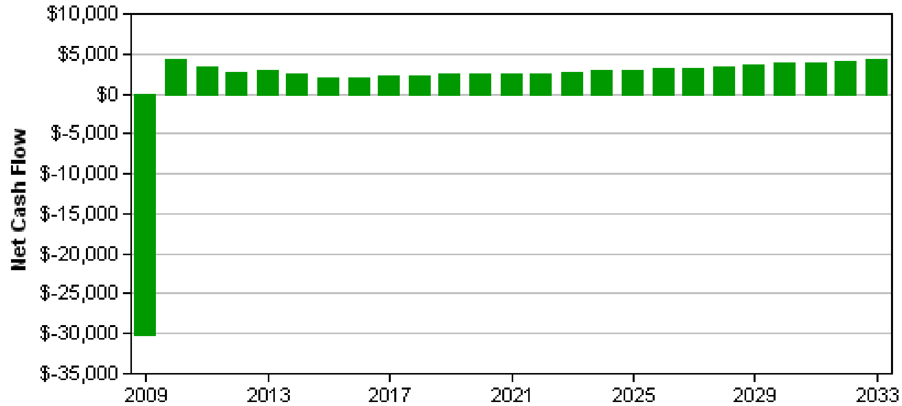
Appendix G - BP Estimator

Annual Net Cash Flow



	Cash Payment	Net Incentives	Annual Electric Bill Savings	Electric Bill Tax Savings	Depreci-ation Tax Savings	Total Net Cash Flow
2009	$-41,723	$77	$1,949	$-612	$10,134	$-30,253
2010		$77	$2,046	$-643	$2,804	$4,284
2011		$77	$2,148	$-675	$1,737	$3,288
2012		$77	$2,256	$-709	$1,098	$2,722
2013			$2,369	$-744	$1,098	$2,799
2014			$2,487	$-781	$618	$2,323
2015			$2,611	$-820	$138	$1,929
2016			$2,742	$-861	$138	$2,018
2017			$2,879	$-905	$138	$2,112
2018			$3,023	$-950	$138	$2,211
2019			$3,174	$-997	$138	$2,315
2020			$3,333	$-1,047	$138	$2,424
2021			$3,499	$-1,100		$2,400
2022			$3,674	$-1,154		$2,520
2023			$3,858	$-1,212		$2,646
2024			$4,051	$-1,273		$2,778
2025			$4,254	$-1,336		$2,917
2026			$4,466	$-1,403		$3,063
2027			$4,690	$-1,473		$3,216
2028			$4,924	$-1,547		$3,377
2029			$5,170	$-1,624		$3,546
2030			$5,429	$-1,706		$3,723
2031			$5,700	$-1,791		$3,909
2032			$5,985	$-1,881		$4,105
2033			$6,284	$-1,975		$4,310

References

http://www.viracon.com/

http://www.mcmorrowreport.com/sfm/articles/energycon.asp

http://energy.opp.psu.edu/

http://www.bp.com/modularhome.do?categoryId=8050&contentId=7035481

http://www.eia.doe.gov/

http://www.fronius.com/cps/rde/xchg/SID-183E5651-A807235E/fronius_usa/hs.xsl/48.htm

http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/

http://www.dsireusa.org/index.cfm?EE=1&RE=1

http://www.owenscorning.com/

http://www.laccdbuildsgreen.org/

http://www.doe2.com/

http://www.umaryland.edu/

Photovoltaic Systems
AMERICAN TECHNICAL PUBLISHERS, INC
HOMEWOOD, ILLINOIS

PSU EUMS Project Documentation

RSMeans Building Construction Cost Data 2009, 67th Edition

Energy Strategic Plan
Los Angeles Community College District